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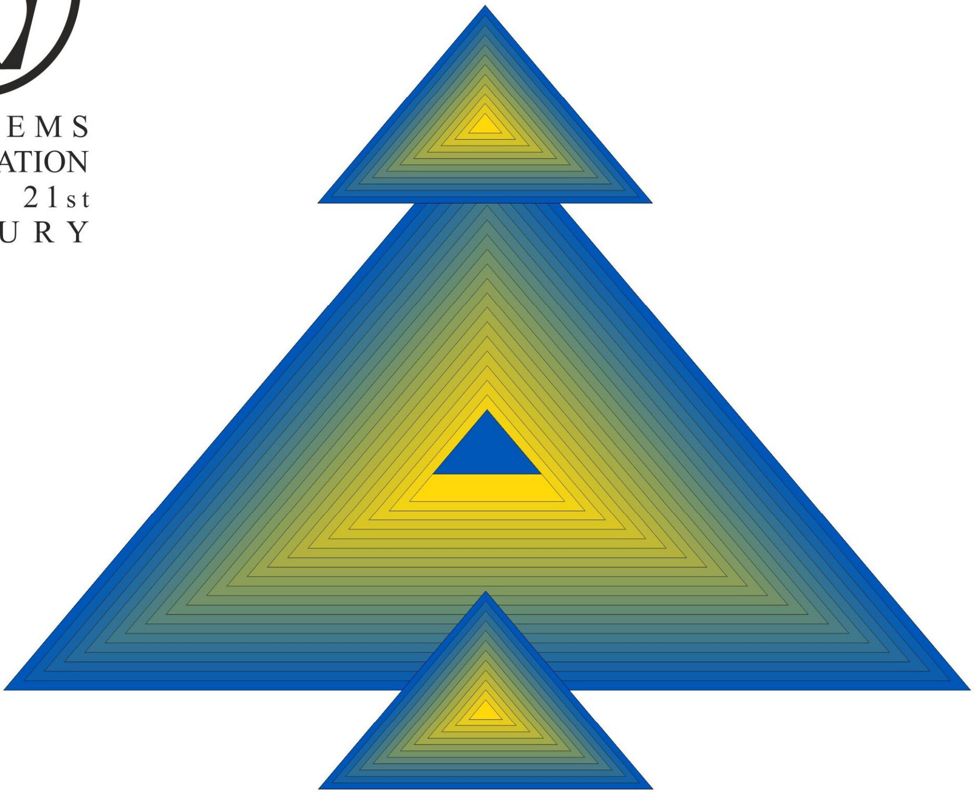

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INTRODUCTION TO THE GEOMETRICAL OBJECTS AND AXIOMS: CONCEPTUAL, DIDACTICAL AND HISTORICAL CONSIDERATIONS

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For a student attending the initial years of the high school, it is not easy to fully realize what a geometrical object is. While speaking, for example, of a triangle, the teacher will underline that its sides have length, but no width and no thickness. However, a pupil has never seen an object of this kind in his daily experience. For, every straight line has a width and a thickness, however minimal they may be. How can we introduce the geometrical objects and, immediately afterwards, the geometrical reasonings so that the learners can accept them not based on a sort of faith act but relying on a real understanding? The best method is to explain their conceptual genesis, also adding some historical elements. Two abstract processes can be identified: the first one gave origin to the abstract objects, the second one to the propositions (axioms) on which the relations of such objects rely. Therefore, we suggest that the teacher dedicates two lessons to introducing the genetic bases of the geometrical thought before dealing with the mathematical details. In what follows, material for the two lessons is supplied.

The most basic geometric concepts, those of point, line, surface and solid arise for practical purposes and have a physical origin.

Suppose you want to measure the length of a stretch of road, perhaps with curves, or the area of a field. How would you proceed? What would you need?

In the case of the road, if you are in a technologically undeveloped civilisation, the first thing that may come to mind is to equip yourself with a straight measuring instrument - on the length of which you and your companions agree - and apply this instrument from the beginning to the end of the road. If the road is not too tortuous, you will be able to measure its length accurately enough.

In the case of the field, things are a bit more complicated. You will have to agree on a surface to be used as a unit of measurement and see how many times this surface fits into the one you are to measure. If the field has a polygonal form, you can ‘triangulate’ the figure, i.e. divide it into many triangles (see Fig. 1a), and, assuming you know how to calculate the area of a triangle, you can solve your problem. As for figures with curvilinear contours, you can approximate them (which has been done for centuries) to a polygonal shape that reduces the calculation error to within acceptable margins for your purposes.

But let us return to the example of the road: you decide to adopt 10 metres as the unit to measure the road. You therefore build an articulated measuring instrument 10 metres long and start measuring (Figure 1b).

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Figure 1a
Example of Triangulation of a Polygonal Figure

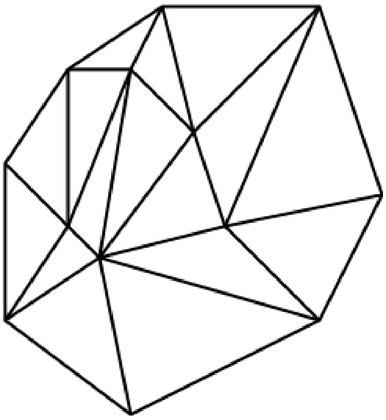


Figure 1b
An Articulated Measuring Instrument

What do you care about your instrument? Does the width matter?

Obviously, your instrument must have a width because there is no such thing as an object that has a length but no width. Furthermore, on a practical level, an instrument that is too thin or one that is too thick would both be uncomfortable, albeit for opposite reasons. However, width in no way enters the measuring process, nor into the result. Only length enters it.

What have you done? You have *abstracted* from the width of the instrument.

In effect, you are creating a new ‘object’, an ‘ideal object’ that only has a length, but no width. You did this, simply because you did not need the width. It is, therefore, easy to understand what it means that, from now on, you will use instruments that, ideally, only have a length.

A new ‘object’, an ‘ideal object’ that only has a length but no width, has been created. This happened because the width played no role in the measuring process. It is, therefore, easy to understand what it means that, from now on, instruments that, ideally, only have a length will be used.

But let's move on: we have built a 10-metre measuring instrument, but who's stopping us from building it longer, perhaps by putting it in a case from which it can be unrolled (Figure 2)? Ideally, we could build instruments as long as we want. Of course, in practice, we have physical limitations: it would be quite inconvenient, for various reasons, to have a measuring instrument 10 km long!

Figure 2
A Measuring Instrument Inserted in a Case

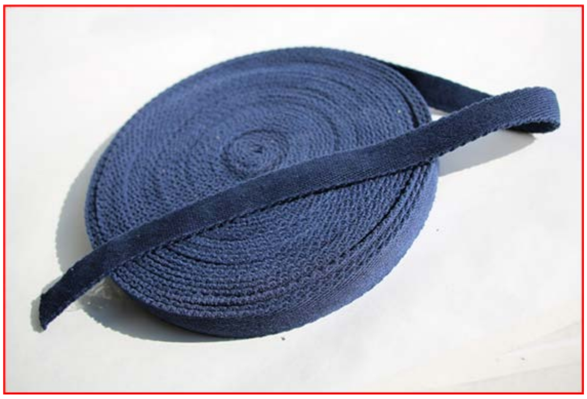
Then we get an idea: why not add to our 'ideal segment' another property such that it can be extended indefinitely on both sides? This is very convenient: at least in theory, we would have a measuring instrument that, in one go, tells us immediately how long a certain length is, at least if it is rectilinear.

We then transform our ideal segment into an unlimited straight line. We have thus arrived at the *straight line of geometry* (which means 'measuring the earth'). An *abstract entity*, but one that is useful for performing concrete operations.

With this, we did not claim to give a precise definition of what a straight line is, but we did get an idea of how such a concept was originally formulated. For the surface as an entity that has a length and a width, but not a thickness, its genesis is analogous: thickness is not necessary if one wants to measure a field or any other surface. Instead, a comparison surface is paramount. It is an ideal surface, namely without thickness. Let us assume, then, that in the abstract world we are constructing, there are also surfaces without thickness.

We now come to something similar, but a little more subtle: you are given a strip of cloth, like, for example, the one in the picture (Figure 3). You are asked to measure it. You unroll it and begin to apply a 1m long instrument. Of course: if the strip is very long and you have no way of marking the subsequent 1m measurements, it is almost impossible for you to measure the strip.

Figure 3
A Very Long Strip of Cloth the Learner Must Measure



One possible way to proceed is to mark, for example, with chalk, successive divisions, each one meter long. What is of interest about these divisions? Perhaps their length, or their width? Absolutely not: it only matters that they indicate a series of "points" of the piece of cloth so that one can say, "This is one meter," "This is another meter," and so on.

There arises, then, the idea of considering an entity whose length or width are of no interest, but only its capability to indicate and separate elements within a rectilinear continuum is important. A new geometric entity has been thus constructed. It holds the paradoxical but not contradictory property of having no parts. It is the pure indication of a subdivision operation: it is the geometric point.

In practice, there is nothing analogous to the geometric point, but it is an abstraction that is convenient: its use is convenient. This perhaps explains the origin of the much discussed and criticized Euclidean definition of a point as "that which has no parts." (Euclid 2008, p. 6).

What has been described can be called the first process of abstraction, that is, one in which abstract objects are constructed that have the described origin and on which certain operations are performed. The Egyptian and Babylonian civilizations had already developed this first process of abstraction.

What I have given here is the idea of an empirical, purpose-related genesis of geometric entities. One can also think of a conceptualist genesis: the idea of a point is reached because, starting from very small spheres, men are able to think of a progressive reduction of such spheres until reaching the abstract idea that there only one unextended point remains. I am, likewise, convinced that without practical necessities, the idea of a dimensionless point would have never been reached.

Finally, an even more idealistic position than conceptualism is that of those who believe that mathematical ideas are innate. This is Platonism.

To summarize: what are the characteristics of geometry analysed so far? A world of abstract objects has been constructed. It is derived from specific necessities of practical life, but the abstract objects have different features in respect to the ordinary ones. Specifically, they lack some ordinary properties because every ordinary object is extended in the three spatial dimensions, whereas the abstract point has no dimension, the abstract line has one, and the abstract surface has two. These new objects, though conceived because of practical reasons, create a geometrical world which is not our perceptive and physical universe. It is an abstract world. For the learners, it might be interesting to know that this level of abstraction had already been obtained by the Egyptians and by the Babylonians.

An example drawn from Egyptian geometry can be useful. Let us consider the problem 56 of the Rhind papyrus, from which it is possible to deduce that probably the Egyptians also knew some trigonometric functions useful in the pyramids' construction.

Given a cone (whose section with a vertical plane is shown in Figure 4a), one defines «conicity» C as the ratio between the difference of the diameters D and d of two parallel sections of the cone and the distance L between these two sections if measured axially. Therefore, conicity only depends on the cone's opening angle. It is trivial to show that the identity holds.

$$C = \frac{D-d}{L} = 2\tan\frac{\alpha}{2}$$

Analogously, for pyramids (in our case we are only interested in those with a square base), «taper» is defined (Figure 4b).

Figure 4a
Exposition of the Concept of Conicity

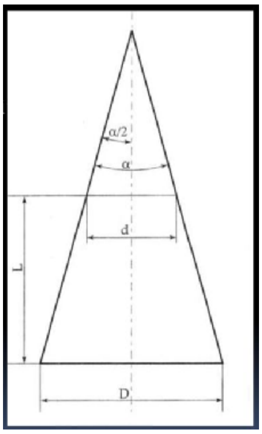
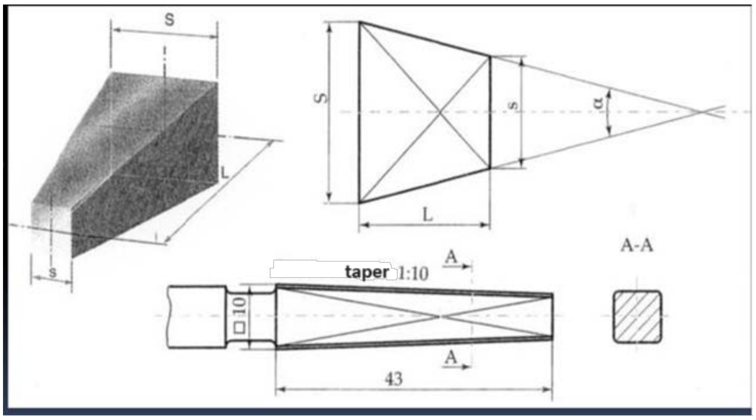


Figure 4b
Exposition of the Concept of Taper



The Egyptians used exactly this concept and called it *seqt*. The *seqt* represents the inward slope of a wall and is simply half the taper.

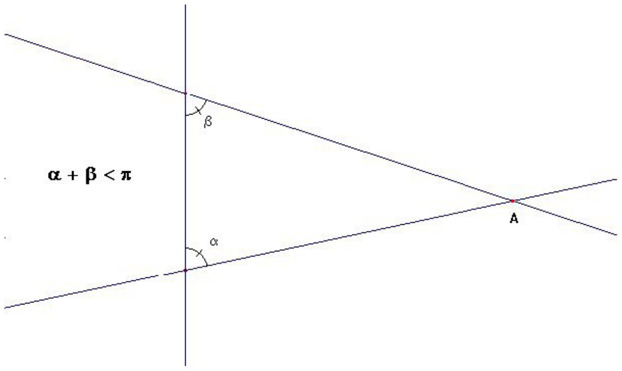
Problem 56 asks for the *seqt* of a square-based pyramid whose side is 360 cubits and whose height is 250 cubits. To solve the problem, Ahmes (the writer of Rhind papyrus) divides 360 by 2. He then divides the result by 250, so obtaining the tangent of α/2, whose value is expressed as $\frac{1}{2}+\frac{1}{5}+\frac{1}{50}$.

This example shows that the Egyptians were able to deal with abstract geometrical objects. The Egyptians and Babylonians knew how to calculate lengths, areas, and volumes. They already knew some intuitively deduced truths, such as the fact that the area of a rectangle is base by height and the area of a triangle is base by height divided by 2. They were able to combine these simple truths to obtain more complex truths. They even knew some specific cases of the so-called Pythagorean theorem.

However, how have we proceeded so far? Our ordinary intuition has been applied to abstract objects. The foundations of geometric reasoning have not been established, or rather, they have been assumed to be identical to those of ordinary reasoning. Since, however, geometric reasoning concerns abstract entities, it seems illegitimate to apply all and only ‘ordinary’ reasoning to them. We would need starting points specifically designed for abstract objects. In other terms: it is necessary to establish a set of initial propositions which hold for the objects of the abstract world we have created. Such propositions are not proved, but they are the bases on which all the other properties of the abstract world will be proved. Therefore, there is a *first process of abstraction* through which we construct abstract objects and a *second process of abstraction* through which the basic laws governing such an objectual world are established. For the students to fully understand geometrical thought, it is important that they grasp the nature of the two steps. The merit of the second step is of Euclid (IV-III B.C.) who carried out it in his seminal *Elements*. He stated the following fundamental propositions as axioms or postulates.

> 1. Let it have been postulated to draw a straight line from any point to any point.
> 2. And to produce a finite straight line continuously in a straight line.
> 3. And to draw a circle with any centre and radius.
> 4. And that all right angles are equal to one another.
> 5. And that if a straight line falling across two (other) straight lines makes internal angles on the same side (of itself whose sum is) less than two right angles, then the two (other) straight lines, being produced to infinity, meet on that side (of the original straight-line) that the (sum of the internal angles) is less than two right angles (and do not meet on the other side. See Figure 5). (Euclid 2008, p. 7).

Figure 5
A Representation of Euclid’s Fifth Postulate, the Famous Axiom of Parallels



The first three axioms state that Euclidean geometry is the geometry of the ruler and compass. No other tools: given two points, it is possible to draw the segment joining them; this segment can be extended as far as one wants (by line, Euclid always means a segment, never an infinite line, unless he specifies otherwise) and one can draw a circle, obviously with a compass. Therefore, only constructions made with a ruler and compass are permitted: a signed a ruler or a square cannot be used. Solving a problem, in this context, means solving it with a ruler and compass.

A methodological reflection is useful in teaching: the world of Euclidean geometry has been created. To prove theorems of this universe, one must only use Euclidean tools. Obviously, other choices can be made, for example, allowing the use of richer tools, such as a square, a signed ruler, or an ellipsograph. It will be useful to remind the learners of constructions which cannot be done with a ruler and compass. Examples: 1) duplicating a cube of a given edge, namely, to construct a cube whose volume is double that of a given cube. In itself, the cube is constructible with a ruler and compass, but not if one claims to construct a specific cube that has twice the volume of a given one. 2) Construct a square equivalent to a circle. Separately, a circle and a square are trivially constructible with a ruler and compass, but not if you set the previous specific condition. Therefore, it is useful in teaching geometry to get across the idea that mathematics is a discipline related to the means of construction one decides to use. This aspect is reflected in the postulates. Mathematics is not a kind of 'machine to prove theorems', but a careful analysis of the limits of the conceptual tools one decides to use. Of course, one can decide to use all mathematics, but one must be aware that it is, nevertheless, a choice. That is why great mathematicians have often given different demonstrations of the same theorem.

Let us come back to the analysis of postulates: The fourth axiom tells us that the measure of a right angle depends neither on the way in which we arrange it nor on its position in the Euclidean plane. In other words: of the right angle, but of all angles in general, only the measure has geometric significance, not the position, nor the dimensions of the sides.

A further consideration is helpful from an educational perspective: Every system of axioms preserves something. It can also be interpreted as a set of transformation rules with invariants. Without invariants, there would be no mathematics or physics. The most general Euclidean transformations are shape-preserving similarities (relations between segments and angles). The fourth axiom, which claims the invariance of the right angles (and, in fact, of every angle), can be interpreted as the first step towards the theory of similarity and, hence, towards the Euclidean concept of form.

The fifth is the famous postulate of parallels. Euclid, in fact, defines (def. XXIII) as parallel two lines that do not meet each other on either side. Then postulating that if a line falling between two others forms internal angles on the same side (conjugate) less than two right angles (such that the sum is less than two right angles), the two lines, prolonged indefinitely, will meet on the side where the sum of the angles is less than two right angles, is equivalent, by trivial contraposition, to postulating that 'if two lines do not meet on either side (i.e. they are parallel), then a line falling between them forms conjugate angles equal to two right angles'. Therefore, the fifth postulate expresses a condition of parallelism.

A conceptual division of the postulates into groups could be this: axioms 1-3 define elementary constructions that can be performed by ruler and compass; axiom 4 establishes a uniformity property of the Euclidean plane; and axiom 5 establishes angular relations connected to the incidence of lines. This subdivision is perfectly fine.

However, another is also possible: axioms 1,3,4 concern finite properties of the Euclidean plane, while axioms 2 and 5 regard the behaviour of lines at infinity (prolongation and parallelism). It is a well-known, though very interesting, story that, since antiquity, attempts have been made to prove the fifth postulate as a theorem deducible from the other four because its infinite character and conceptual complexity seemed to collide with the simplicity of the other four. Proclus (412-485 A.D.) already tried to deduce the fifth postulate from the other four. History has taught us that Euclid, to whom the entire theory of parallels is probably due, was much wiser than his successors, up to Gauss (1777-1855).

Postulate 2 seems, so to speak, innocuous, but it is not, like any other proposition concerning infinity, even in its potential form. Riemann (1826-1866) did, in fact, find a geometry, perfectly consistent with postulates 1,2,4, but in which the line has finite length.

In these considerations, two processes of abstraction have been considered: the former concerns the creation of abstract geometrical objects; the latter, which is more difficult and refined, regards the construction of a language and of a series of basic assumptions that are specific for such objects. It represents the first and fundamental step which progressively led to a formalized language for mathematics. For the students to acquire a satisfactory view of geometry and of the other mathematical abstractions, we consider it crucial that they are introduced to this discipline through two historical-methodological lessons (for the importance of the history of mathematics in an educative context, see, e.g., Bussotti 2012, 2013, 2017, 2021. With regard to the methodological aspects of mathematics education, see e.g., Mudaly & Mpofu 2019, Ersoy & Drağyar 2022, Kurban 2024), whose development has been described here.

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THE RELATIONSHIP PATTERN BETWEEN PERSONALITY TRAITS AND LEARNING RESPONSIBILITY

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Abstract

As the interest in the shift from teacher–centred paradigm to student–centred learning pedagogies has increasingly grown in popularity nowadays, it should come as no surprise that scholars and academicians have given their attention to the concept of self–engagement in the learning process. In an attempt to explore the role of personality in self–engagement, this paper aims to assess the relationship pattern between individuals' personality traits and their learning responsibility. A total of 358 students attending a university were recruited for the study. The Ten–Item Personality Inventory (TIPI) and The Learning Responsibility Scale were administered. The findings revealed that learning responsibility correlates positively with emotional stability, conscientiousness, and agreeableness. However, the associations between extraversion and openness with learning responsibility are negative and not significant. The findings have also demonstrated that although agreeableness does not display a significant predictive power, both emotional stability and conscientiousness have a significant influence on learning responsibility.

Keywords: *personality traits, learning responsibility, student–centred learning, individual differences, The Big Five*

Introduction

Academics have focused on comprehending the processes of self–learning due to the rising interest in self–engagement in the learning process. As the interest in the shift from teacher–centred paradigm, predicated on the implicit belief that knowledge could be readily transmitted from the teacher's mind to the learner's (Bodner, 1986), to student–centred learning pedagogies has increasingly grown in popularity in the field of education (Lea et al., 2003; O'Neill & McMahon, 2005; Taylor, 2013), it should come as no surprise that scholars and academicians have given their attention to the concept of self–engagement in the learning process. Although being an elusive concept to define, student–centred learning highlights approaches to teaching and learning that prioritize the responsibility and involvement of students in the learning process over the actions of the teacher (Lea et al., 2003). Student–centred approach epistemologically has roots in a constructivist philosophy, emphasizing learners' active engagement in constructing their own knowledge (Dinata et al., 2023; Dunbar & Yadav, 2022; Mraougkas, 2023) and suggesting learners to organize their own schedules in the learning process (Augustini et al., 2021), where learners construct and learn their understanding, collect and process data, compare it to previously collected data, and update regulations (Golder, 2018) rather than repeating back to themselves what they have been told or read (Bodner, 1986; von Glasersfeld, 1995).

It is argued that self–regulation and the construction of cognitive frameworks through abstraction and reflection are prerequisites for the constructivist viewpoint (von Glasersfeld, 1995). The term "self–regulation" here describes the capability of students to comprehend

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and regulate their own learning environments (Schraw et al., 2006), and emphasizes the idea that learners possessing awareness, efficient learning skills, and taking responsibility for their learning process as well as activities would yield positive learning results (Augustini et al., 2021). Dividing the self–regulated learning perspective into categories such as self–efficacy perceptions, commitment to attain the given goal, and strategy use, Zimmerman (1986) suggests that when students actively participate in their own learning process metacognitively, motivationally, and behaviourally, they can be said to be self–regulated, and instead of depending on instructors, peers, or others, these pupils take the initiative and lead their own attempts to learn novel abilities and knowledge.

A review of literature suggests that effective learning takes place when the learners apply not only proper techniques or study skills but also positive attitudes for learning, a strong drive, and self–regulated behaviours (Erişti, 2017; Ning & Downing, 2012). Self–regulated learning establishes a base by allowing individuals to take charge of their learning process, including goal planning, effective time management, and progress tracking (Etkin, 2018; Nilson, 2013; Oates, 2019; Zimmerman, 2002), instead of being taught by the instructor, who is the principal figure, the "sage on stage," possessing knowledge and imparting it to the learners (King, 1993). Defining self–regulated learning as a process where learners establish or set objectives for their own learning path, Pintrich (2000) has highlighted the involvement of monitoring, regulating, and managing cognitive processes. As learners become more adept at self–regulation, they are likely to recognize and realise the benefits of taking responsibility and being in charge of their own learning. Individuals' learning responsibility is fostered when they take charge of their educational path while discovering to observe, assess, and adapt the ways in which they learn, given that through actively seeking answers and adjusting their techniques to match their learning needs, learners actively seek out solutions and develop a sense of accountability. This sense of accountability or responsibility for one's own learning, as suggested by Ayish and Deveci (2019), appears to be vital for school, personal, and professional advancement as well as achievement.

Learning responsibility, in this respect, can be defined as making attempts to learn, upholding and sustaining this responsibility, and examining the process of learning by assessing its outcomes (Gökdağ Baltaoğlu & Güven, 2020). However, as Allan (2006) has pointed out, a review of the literature indicates that the term has been included in various concepts and structures, such as "self–directed learning", "autonomous learning," "self–controlled learning," "self–regulated learning" and so on. To Allan (2006), although the construct has been described in a variety of ways, it essentially encompasses certain characteristics such as personal autonomy along with self–regulated learning, participating in the learning process in an active way, which involves taking initiative, embracing and taking responsibility for the consequences, and finally independent learning. In spite of the various interpretations of the term, it essentially encompasses certain characteristics such as figuring out learning objectives, analysing one's own methods of learning, encouraging oneself to learn and be committed to learning, collaborating with peers, and developing novel strategies when goals set are not met (Gökdağ Baltaoğlu & Güven, 2020).

In the learning process, both non–cognitive elements like personality and cognitive elements like skills and general intelligence play crucial roles. As Barros et al. (2021) assert, when academic levels increase, personality tests get more predictive power while cognitive skills tests lose predictive power, and the way that students interact with their academic settings can be influenced by specific personality factors, which can have an impact on how skills and academic achievement are related. According to Mathews et al. (2006), personality is important in children's school experiences, given that it influences classroom conduct, contributes to academic achievement, and shapes relationships with classmates and instructors. The authors conclude that even in the classroom, students engage in much more than just studying. They are driven to react differently to pressures and life events, manage their learning objectives, try to deal with academic and interpersonal challenges, and reflect on their own accomplishments and mistakes. Different personality traits have varied effects on various mental processes that regulate a student's well–being, social skills, and academic performance. Therefore, certain personality traits can influence how students engage with their academic environments, affecting the relationship between skills and academic success (Eilam et al., 2009; Swanberg & Martinsen, 2009). Allan (2006) expanded on this by emphasizing qualities like personal autonomy and self–regulated learning as essential to taking responsibility for one's learning path. Thus, personal traits and developing a sense of responsibility are closely related since an individual's personality has a significant effect on how they perceive, embrace, and carry out their commitments. Following the development of the five–factor model of personality, commonly known as the "Big Five," and the qualities of which have been identified as openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism, a significant association has been shown between personality and learning (Angelini, 2023; Feist, 1998; Swanberg & Martinsen, 2009). A review of literature has also revealed the associations between personality traits and academic performance (Cao & Meng, 2020; De Feyter et al., 2012), academic motivation (Clark & Schroth, 2010); emotion regulation strategies (Barańczuk, 2019); learning performance (Smiderle et al., 2020); academic self–efficacy (Rivers, 2021); emotional intelligence (Rosales–Pérez et al., 2021), and so on.

To Cazan and Schiopca (2014), self–directed learning, or learning responsibility as termed in Allan's (2006) study, is a skill that can be developed by all learners, however, to varying degrees depending on personality factors ranging from motivation, self–confidence, conscientiousness, openness to new experiences, to other traits. Bidjerano and Yun Dai (2007) expanded on this and asserted that "Big Five" traits can be applied through self–regulatory inclinations and behaviours by illustrating that conscientiousness, for instance, encompasses dependability and accountability, as well as the capacity to plan, organize, and persevere in pursuit of success. Hence, acceptance of the relationship between personality traits and learning responsibility is essential to appreciating the variations among individuals in how they approach and carry out their duties throughout a range of life domains. Although the capacity to perceive and fulfil obligations is included in the idea of responsibility, it is acknowledged that personality traits have a substantial influence on an individual's tendency toward responsible action. Examining such a relationship could provide a detailed comprehension of the basic principles that urge responsible conduct. It would be possible, in this way, to grasp the fundamental underlying mechanisms by exploring how personality traits impact the formation and development of learning responsibility. To illustrate, as De Feyter et al. (2012) and Swanberg and Martinsen (2009) argued, it is thought that personality traits, such as conscientiousness and neuroticism could be highly related to performance and point out that those possessing a strong sense of conscientiousness could be better organized and self–driven, which would allow them to carry out their duties more regularly and effectively. On the other hand, as they believe they have less influence over the outcome, those who have a stronger external locus of control may find it challenging to accept responsibility. Additionally, exploring the relationship patterns between personality traits and learning responsibility may have practical implications for educational settings through comprehending how various personality types react to interventions meant to foster responsibility in the learning process. In this way, it would be likely to customize learning designs and appropriate interventions to meet the different needs of people with diverse personality types, which would enhance their ability to conduct themselves more responsibly. In conclusion, it is evaluated that research into the connection between personality traits and learning responsibility could have the potential to advance theoretical knowledge as well as real–world applications in educational settings. Through the clarification of the complex and multifaceted interactions among these variables, it would be possible to support initiatives that attempt to encourage taking responsibility and personal growth in a variety of settings in educational contexts. Considering the aforementioned, this study is thought to close a gap in the literature by analysing possible specific associations between certain personality traits and learning responsibility. To be more precise, the aim of this study was to explore the relationship pattern between personality traits and learning responsibility. The research questions are as follows:

1. What is the relationship between students' perceived learning responsibility and several personality traits, including openness to experiences, agreeableness, emotional stability, conscientiousness, and extraversion?
2. Do personality traits predict students' feeling of learning responsibility?

Research Methodology

Research Design

In the current study, a correlational research design was employed to explore and investigate the associations between learning responsibility and personality traits. The correlational approach, which involves measuring two or more variables and evaluating their connection, was used in an effort to examine links between variables. The primary goal is to determine whether and to what extent changes in one variable are associated with changes in another variable.

Participants

Applying the random sampling method, 358 students attending a university were recruited for the study in the 2022–2023 academic year in İstanbul. The participants were invited to give responses to the scales online with the assurance that their answers would remain confidential, and that participation was voluntary. Data for 12 respondents were removed in view of insufficient marking. A total of 346 (61% male, 39% female) participants completed the data collection tools. Table 1 presents the demographic features of the students recruited for the study.

Researchers may have used a specific sampling method (e.g., random sampling, stratified sampling) to ensure that participants are selected in an unbiased manner from the target population.

Table 1
Participant's Demographic Characteristics

Demographic Information		*f*	%
Gender	Female	136	39
	Male	210	61
Age	18–20	270	78
	21–23	70	20
	24–26	6	1.8
	27+	–	0
Department	Faculty of Machinery	87	25
	Faculty of Civil Engineering	67	19
	Faculty of Chemistry and Metallurgy	71	21
	Faculty of Economics and Administrative Sciences	44	13
	Faculty of Naval Architecture and Maritime	36	10
	Faculty of Arts and Sciences	41	12
Total		346	100

Data Collection Tools

The Ten–Item Personality Scale

Five major personality traits are measured by the Ten–Item Personality Scale, which was initially developed by Gosling et al. (2003) and translated into Turkish by Atak (2013). Consisting of 10 items, the 7–point scale has five sub–dimensions: openness to experiences, agreeableness, emotional stability, conscientiousness, and extraversion. The internal consistencies of the dimensions were calculated at .83, .81, .83, .84, and .86, respectively. Ten items and a five–factor model explaining 65.21% of the variance were produced using exploratory component analysis and language validity (correlations between 0.92 and 0.97) (Atak, 2013).

The Learning Responsibility Scale

Developed by Erişti (2017), the 28–item learning responsibility scale is divided into four subcategories, including preparing for learning (seven items), active involvement in learning (nine items), monitoring learning outcomes (eight items), and enhancing learning (four items). With four components and 28 items, the explanatory power was found to be around 54% of the total variance, explaining the behaviors related to learning responsibility ($\chi 2$: 6856,93, df: 351; $p <.000$). According to the factor–based analysis, the subcategories had .86, .86, .81 and .75 reliability levels. The reliability coefficient obtained for the whole scale is $\alpha = .92$.

Data Analysis

Correlational analysis was employed to examine the link between personality traits and the learning responsibilities of the participants. The data from this study were analysed using the SPSS 21.00 software program. Regression analysis, which enables researchers to comment on the variance in the dependent variable caused by the independent variable, was also carried out in order to identify and explain the predictive power of the independent variables (personality traits) over the dependent variable (learning responsibility).

Research Results

Before the correlation and regression analysis, the Skewness and Kurtosis test of the variables were conducted to ensure that the data set displayed normal distribution. Table 2 presents the values of the Skewness and Kurtosis test of the variables.

Table 2
The Skewness and Kurtosis Test of the Variables

		Descriptive Statistics			
	N	Skewness		Kurtosis	
		Statistic	*SE*	Statistic	*SE*
Learning Resp.	346	–.421	.298	0.088	.470
Openness	346	–.109	.283	1.089	.372
Agreeableness	346	–.132	.238	–.631	.476
Emotional Stab.	346	.197	.209	.287	.378
Conscientiousness	346	–.314	.215	–.754	.366
Extraversion	346	–.995	.238	1.380	.472

As seen in Table 2, the values of the variables regarding the Skewness and Kurtosis test demonstrate that the data set displays a normal distribution.

In Table 3, the values of descriptive statistics for dependent and independent variables are presented.

Table 3
The Values of Descriptive Statistics of Variables

Variables	***n***	***M***	***SE***	***s***
Learning Resp.	346	88.20	1.38	14.01
Openness	346	7.14	.17	1.80
Agreeableness	346	9.93	.21	2.15
Emotional Stab.	346	8.14	.19	1.97
Conscientiousness	346	11.38	.18	1.84
Extraversion	346	7.81	.16	1.69

As Table 3 illustrates, the arithmetic means of learning responsibility, openness, agreeableness, emotional stability, conscientiousness, and extraversion range from 7.81 to 88.20. The standard deviations of the variables are 14.01, 1.80, 2.15., 1.97, 1.84, and 1.69, respectively. Variable standard errors vary from .16 to 1.38.

In Table 4, the correlation values of learning responsibility, openness, agreeableness, emotional stability, conscientiousness and extraversion are illustrated.

Table 4
The Correlation Analysis among Variables

Variables	1	2	3	4	5	6
1. Learning Responsibility	1					
2. Openness	–.03	1				
3. Agreeableness	.22*	–.01	1			
4. Emotional stability	.25*	.02	.16	1		
5. Conscientiousness	.22*	–.09	–.02	–.05	1	
6. Extraversion	–.15	.13	.18	.14	–.03	1
N	346	346	346	346	346	346

p < .05

The correlation values among the variables involved in the study are presented in Table 4. As seen, learning responsibility correlates positively with emotional stability (r = .25; p < 0.05), conscientiousness (*r* = .22; *p* < .05), and agreeableness (*r* = .22; *p* < .05). On the other hand, the associations between extraversion and openness with learning responsibility are negative and not statistically significant. Similarly, the relationships between the Big Five personality traits do not correlate with each other significantly.

Regression analysis was carried out after examining the relationship between learning responsibility, openness, agreeableness, emotional stability, conscientiousness, and extraversion. As learning responsibility correlates positively with emotional stability (*r* = .25; *p* < .05), conscientiousness (*r* = .22; *p* < .05), and agreeableness, Table 5 presents the predictive power of emotional stability, conscientiousness, and agreeableness over learning responsibility as the dependent variable.

Table 5
The Regression Analysis for Predicting Learning Responsibility

Variable	*B*	*SE*	*ß*	*t*	*p*
Constant	41.29	11.04	–	3.74	.0001
Agreeableness	.778	.609	.115	1.73	.206
Emotional stability	2.214	.641	.315	3.45	.001*
Conscientiousness	1.891	.714	.241	2.64	.009*
R = .42	R^2 = .28	*p* < .05			

Table 5 gives details on the regression model's independent variables' coefficients, standard errors, and degrees of significance with respect to the dependent variable. The findings show that emotional stability and conscientiousness explain 42% of the total variance in learning responsibility. Although agreeableness does not display a statistically significant predictive power, it is seen that both emotional stability (ß = .31; *p* < .05) and conscientiousness (ß = .24; *p* < .05) have statistically significant influence over the dependent variable, learning responsibility.

Discussion

The aim of the current study was to gain a deeper understanding of the pattern of relationships between personality traits and learning responsibility. Through the analysis, it is aimed at offering a thorough grasp of the ways in which different personality traits influence people's inclination to assume responsibility in educational settings. The findings have indicated several remarkable points to consider. Firstly, it was shown that learning responsibility correlates positively with emotional stability, conscientiousness, and agreeableness. On the other hand, the associations between extraversion and openness with learning responsibility are negative and not statistically significant. The findings have also revealed that although agreeableness does not display a statistically significant predictive power, both emotional stability and conscientiousness have a statistically significant influence on learning responsibility. The interpretation of these findings is based on the relatively limited available research on the issue in question.

As for the significant correlation between emotional stability and learning responsibility, expressed in the first research question, it can be stated that individuals with better emotional stability tend to be more resilient and have the capacity to maintain calm under pressure, and they also take more responsibility for their academic pursuits. As Leong (2022) suggests, individuals with higher levels of emotional stability are better equipped to overcome obstacles by focusing on reality, clear judgment, and critical assessment. In other words, people with emotional stability are able to build a holistic and comprehensive perspective on life's challenges (Chaturvedi & Chander, 2010). Although Cazan and Schiopca (2014) found no association between emotional stability and self–directed learning, which is also referred to as learning responsibility, the findings of a study conducted by Smith et al. (2021) revealed that emotionally stable learners were more motivated in studying, and they were more likely to have more goal–oriented behaviours.

In a similar vein, that conscientiousness is positively related to learning responsibility also illustrates the fact that those who score highly on conscientiousness are more likely to take responsibility for their learning processes and exhibit qualities like organization, discipline, and perseverance. As De Feyter et al. (2012) suggest, learners who are conscientious work in an organized, straightforward, and accurate manner, which paves the way for significantly improved performance on tests or in other assessment procedures. As conscientiousness represents qualities like the urge for achievement, devotion to work (Costa et al., 1991); self–control, responsibility, industriousness, well–organization, complying with rules (Roberts et al., 2014); higher academic achievement (Conrad & Patry, 2012; Noftle & Robins, 2007); motivation (Bidjerano & Yun Dai, 2007), and deep learning (Diseth, 2003), the term itself is closely connected to learning responsibility. This indicates that conscientious individuals are more likely to establish learning objectives, organize their study schedules, and use effective time management in an academic setting. In addition, they display high levels of perseverance that allow them to focus on their academic objectives in spite of interruptions and diversions, in that they have a higher probability of avoiding procrastination and continuing to work steadily toward their learning goals. As Annuar et al. (2023) stated, conscientiousness urges learners to behave more politely and consistently, that is, to be more dependable and trustworthy while fulfilling a given task. Therefore, conscientiousness offers a solid basis for learning responsibility in the classroom by encouraging qualities and actions that promote efficient learning, academic achievement, and responsible engagement.

Agreeableness, referring to qualities like collaboration, honesty, friendliness, adaptability, cooperativeness, courtesy, and kindness (Bidjerano & Yun Dai, 2007; Clark, 2010; Hasanah et al., 2022; Lapitah et al., 2021; Major et al., 2006), also showed a positive association with learning responsibility in the present study. This may suggest a predisposition for agreeable individuals to engage responsibly in learning activities, however, the intensity of this link may vary. Clark and Schroth (2010) in their study found that agreeable individuals were more likely to have intrinsic motivation to pursue knowledge, complete the given tasks, and hold the opinion that attendance at school is essential. Similarly, a study conducted by Lounsbry et al. (2009) also revealed a positive link between self–directed learning and agreeableness. Thus, as a personality trait, agreeableness could have significant impacts on individuals' attitudes toward learning responsibility in that high levels of agreeableness frequently exhibit cooperative behaviour, empathy, and care for others. In addition, given that these people tend to reflect their devotion to personal and cooperative improvement, cherish peaceful relationships, and work hard to satisfy expectations due to their innate desires and motivation, they are more likely to demonstrate a high sense of responsibility in their academic endeavours. Additionally, supportive connections and collaborations for guidance with others and practices that prioritize group or pair works and promote learning responsibility could be other causes of the positive association.

The current study did not pose any positive or significant associations between extraversion and openness, and learning responsibility. Extraversion, connected to the reward systems in the brain (Blagrove & Pace–Schott, 2010), may generally be seen as an aspect of personality that encompasses further specialized qualities, such as superiority, adventure seeking, warmth, and enthusiasm (Saklofske et al., 2012). Matthews (2019) asserts that the trait is frequently not considered a consistent indicator of academic achievement, and extroverts could be better able to handle stress at school. This implies that although extraverted people might be better suited to handle stress in some educational settings, or have other advantages in learning environments, extraversion may not always be associated with a greater willingness to take responsibility for one's own learning. As for openness to experience, the trait refers to being innovative and creative, open to relatively rare ideas, challenging, and unconventional (Bauer & Liang, 2003; Salmon, 2012). Although in the current study, openness to experience as a trait did not correlate with learning responsibility, in some other studies, the trait displayed a positive association with similar fields. For instance, in Cazan and Schiopca's (2014) research, openness to experiences correlated with self–directed learning. Likewise, Bauer and Liang found a significant and positive relationship between openness to experiences with academic and intellectual tasks. In the current study, openness to experience as a trait did not correlate with learning responsibility, which may stem from the fact that learners who score highly on openness may be driven more by a need for novelty and excitement than by a particular dedication to owning and committing their learning path. Rather than making a diligent attempt to control and take responsibility for their own learning process, their involvement in educational settings could be more motivated by a passion for intellectual curiosity.

Conclusions

All in all, the present research on personality traits and their connection to learning responsibility has produced informative results that highlight the complex interactions between individuals' inclinations and their academic engagement. The study highlights the multifaceted nature of personality and seeks to provide a comprehensive understanding of how various personality traits shape individuals' tendencies to take on learning responsibilities. Although some traits, like emotional stability, conscientiousness, and agreeableness, displayed significant correlations with learning responsibility, other traits demonstrated insignificant or subtle correlations. The results highlight how crucial it is to take into account individual differences in personality when formulating interventions meant to support academic performance and learning. The study, however, draws attention to the existing gaps regarding the relationship between the variables that still exist, especially given the lack of previous research on the topic. Further studies should delve into more complex topics, such as the interactions between different personality traits and different learning environments, to improve our comprehension of learning responsibility. In addition, further research into the constant relationship between learning and personality traits has the potential to improve our comprehension of the variables in the learning process. Educators and policymakers may design strategies that enable individuals to develop effective paths in their educational activities, which eventually may pave the way for promoting lifelong learning and individual development.

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STRENGTHENING RESEARCH PEDAGOGY: STUDENT'S ONLINE RESEARCH EXPERIENCES, CHALLENGES, AND EFFECTIVE TEACHING STRATEGIES

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Abstract

Given the growing trend of delivering classes through online and virtual environments, it is vital to gain a nuanced understanding of students' online research learning experiences, the factors that contributed to their choice of learning modality, the challenges they encountered, and the effective online research teaching practices and strategies that supported them in completing the course. Although some studies have looked into this area, there is limited literature on research courses conducted online. Thus, this study attempts to fill that gap. Using a mixed-methods approach, the results revealed that overall, there is a significant difference in the projected performance of 204 asynchronous students compared to their actual achievement. Likewise, a significant difference is also evident in the projected performance of the 67 synchronous students compared to their actual achievement. Furthermore, it is of note that the synchronous students projected higher performance and actually attained better marks, with a significant difference in actual achievement compared to their asynchronous counterparts. Analysis of qualitative data also revealed factors that influenced the disparity, including internet connection issues, communication challenges, learning environment, time management, and group dynamics. Additionally, effective teaching practices that facilitated the completion of collaborative research projects include clarity of learning materials, reasonable deadlines, teacher support and understanding, availability for consultation and feedback, and interactive and engaging teaching methods. Consequently, these results can be used to inform and improve research teaching practices, learning materials design, and assessment tool development. More significantly, it may be used as the basis for institutional policies about online research learning.

Keywords: *online research collaboration, online research experiences, quality education, research pedagogy, sustainable development goals*

Introduction

Online distance learning provides a pivotal opportunity for 21st-century students to succeed in the academe and society as it presents students with training on digital tools and creates an environment for digital interactions (Collins et al., 2022; Kim et al., 2005). Additionally, e-learning has empowered learners by instilling self-learning and the capacity to winnow and discriminate information from the large amounts of data available in the online setting (Chen et al. 2012; Day et al. 2021). Students may have the freedom to study at their own pace and focus on the information and concepts more significant to them (Koskela et al., 2005). This is especially true among students with a higher level of independence and self-regulation as they may allot the needed time for more challenging topics and less time on topics, they already have background knowledge (Gilbert, 2015). Responding to the growing trend of

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delivering classes through online and virtual environments, this study delves into the factors that shape the choice of online research learning modalities – asynchronous or synchronous. Asynchronous online learning prioritizes flexibility as learning is mediated and supported by technologies such as emailing, learning management systems, and messaging apps. In this modality, the teacher and students may not be online at the same time. Teachers may post announcements, learning materials, tasks, and discussion questions which students may access anytime and anywhere, affording them enough time to complete projects and tasks (Hrastinski, 2008). Conversely, synchronous online learning is mediated by videoconferencing applications for real-time interaction between teachers and students. With the social and interactive nature of SOL, student inquiries and concerns are directly and immediately addressed, and engagement with lesson contents and learning materials is done in real time (Hrastinski, 2008). Although there is limited literature on online research learning practices and pedagogy, it is highly valued and necessary in upgrading the research capacity of higher education institutions (Durante, 2022). Moreover, in an online research learning environment, literature has shown that learners become more flexible and are able to overcome logistic and physical barriers so that they can participate in research collaborations anytime and anywhere (Collins et. al., 2022; Chin 2020). Factors that contribute to the effectiveness of online collaborative research learning experience include: (1) recognizing the diversity of values, experiences, and personalities of collaborators, (2) assigning roles of members of the collaboration team, (3) how the members build relationships and their interdependence with each other, (4) how ergonomic, flexible, and adaptable the processes used by the groups are, (5) how the members of the group learn knowledge, skills, and expertise, and (6) what motivates the members of the research team (Durante, 2022).

However, despite the emerging trend of online research learning delivery, there are still challenges identified, including cognitive barriers such as information overload and lack of focus, communication barriers, and educational and environmental barriers arising from socioeconomic disparities (Kohan et al., 2017). Issues such as information overload, the heavy workloads from online courses, and increased demands on time management have been linked to heightened stress levels among students (Chen et al., 2012; Kohan et al., 2017; Moawad 2020). Similarly, mental health challenges among students, like anxiety and depression, have been associated with online learning environments (Day et al., 2021; Hillard et al., 2020; Kohan et al., 2017; Moawad, 2020). Factors identified that contribute to these mental health challenges include lack of guidance, information overload, and challenges in collaborative group settings (Hillard et al., 2020). To address this, reducing academic stress has been shown to enhance students' readiness for self-directed learning, crucial for navigating online learning environments effectively (Heo & Han, 2018). Other issues include constraints on hands-on laboratory and experiments for quantitative research (Chin, 2020), while qualitative data collection, such as interviews, may be a fundamentally different experience in an online setting (Deakin & Wakefield, 2014). According to a few studies (Carnegie Dartlet, 2020; Day et al., 2021; Price et al., 2020), many students, particularly those in the STEM fields, found it challenging to replicate virtual aspects of research involving laboratory and field studies.

Despite these, academic institutions still forge ahead in delivering research classes online to ensure the continuity of learning and provide thousands of students the chance to develop research skills and participate in research initiatives (Sloan et al., 2020). The locale of the current study is one of these academic institutions which continued to deliver research courses among senior high school students in Luzon, Philippines, as part of the curriculum requirement for the completion of secondary education and pre-requisite to higher education admission. As it was the first time that students engaged in research, and to be delivered online at that, this study aimed to identify students' expectations and anticipated performance in the online research course compared to their actual achievement, the factors that contributed to their choice of online learning modality, the challenges they encountered, and the effective online research teaching practices and strategies that supported them in completing the course. More specifically, this study aims to shed light on the effectiveness of online research teaching practices and strategies that were used to address the challenges experienced by students, as well as identify the factors that contributed to the students' online research learning experience. The nuanced understanding of effective teaching practices and strategies could provide relevant information to administrators and research teachers to better support students' needs in online research. The information gathered may be useful in revisiting the pedagogical practices in an online research learning environment.

The study may have a significant impact on the academic institutions' advocacy of delivering quality Education and Pedagogy for Filipino Learners. More specifically, this study sought to answer the following research questions:

1. What is the SHS students' anticipated performance in online research learning compared to their actual achievement?
2. Is there a significant difference in the SHS students' anticipated performance in online research learning and their actual achievement?
3. What are the factors that influenced the choice of senior high school students' learning modality?
4. What are the factors that shaped SHS students' experiences and achievements in online research learning?
5. What are the teaching practices and strategies utilized by the research teacher that enable the effective delivery of online research learning?

Research Methodology

General Background

The present study adopted the mixed methods embedded research design. This research approach enabled the researcher to collect both quantitative and qualitative data about the students' experience in the online research learning environment, with the latter providing a supportive role to clearly understand the phenomena under study (Creswell, 2006). The study is limited to the online research classes conducted during the academic year 2021-2022, amidst the height of the pandemic. It was implemented for five months, starting at the beginning of the first semester and was completed by the end of the same semester.

Sample Selection

The study involved 271 self-selected senior high school students of a government-run laboratory school in Luzon, Philippines with any one of the following experiences: (1) enrolled in online research learning for AY 2021-2022, (2) categorized under academic strands Humanities and Social Sciences (HUMSS), Accounting, Business and Management (ABM), and Science, Technology, Engineering and Mathematics (STEM); and (3) currently grade 12 level. The students have been engaged in online learning for two semesters in both synchronous and asynchronous modalities. The school empowered the students to choose which learning modality they would use in attending their classes. Responses from participants who did not meet any of the three criteria for participation were not included in the analysis. Informed consent was sought from the participants, and they were informed that they could withdraw their participation at any point during the conduct of the study.

Table 1 shows the specific learning modality chosen by the participants of the study.

Table 1
Summary of Participants' Profile

Academic Strand	Number of participants *N* (%)	Chosen Learning Modality	Total *N* (%)
Humanities & Social Sciences	50 (18.45)	SOL AOL	11 (22) 39 (78)
Accountancy, Business & Management	61 (22.51)	SOL AOL	12 (19.67) 49 (80.33)
Science, Technology, Engineering & Mathematics	160 (59.04)	SOL AOL	44 (27.50) 116 (72.50)
Total	271 (100)	Total SOL Total AOL	67 (24.72) 204 (75.28)

Instrument and Procedure

The data were collected using retrospective self-report questionnaires. A retrospective self-report questionnaire was considered appropriate because participants were asked to characterize their subjective experiences in online research learning (Robinson, 2014; Schwarz, 2004). The first questionnaire administered at the beginning of the semester was divided into four sections (1) participants' academic strand, (2) their choice of learning modality, (3) their anticipated performance, and (4) the open-ended section asking about the reason behind the choice of modality. Likewise, the second questionnaire administered at the end of the semester was divided into four sections (1) participants' academic strand, (2) their choice of learning modality, (3) their actual achievement, and (4) the open-ended section asking about their experiences and challenges that contributed or constrained their performance in the online research course, as well as the teaching practices and strategies that addressed them. The clarity, accuracy and content validity of the questionnaires were reviewed by three experienced research teachers and researchers.

The research was reported to the academic institution's research management office for approval to conduct as well as to the head of the institution supervising the laboratory school. The questionnaires were administered online via Google Forms. It took approximately 10-15 minutes to complete each questionnaire. The online survey was used because of the lockdown in the country.

Data Analysis

To address the research questions, both quantitative and qualitative analyses were used. Specifically, the first and second research questions were answered with data gathered and analyzed using quantitative techniques while research questions 3, 4, and 5 utilized qualitative methods. For the quantitative analysis, the data was encoded in Microsoft Excel and Statistical Package for Social Sciences v. 22. The mean score ($\bar{x}$) and standard deviations (*SD*) for anticipated and actual achievement by students during online learning were computed. The mean score was interpreted using the following verbal interpretations: 5.50 to 6.0 (Excellent), 4.50 to 5.49 (Very Good), 3.50 to 4.49 (Good), 2.50 to 3.49 (Satisfactory), 1.50 to 2.49

(Conditional Pass), and 1.0 to 1.49 (Fail). Afterwards, the mean scores were subjected to Paired Samples T-Test to see if there is a significant difference between the anticipated and actual achievement in online research learning of students in synchronous and asynchronous classes. For the qualitative data, they were analyzed using NVivo version 10 and Clarke and Braun's Thematic Analysis protocol. Open codes and axial codes were identified, categorized, and then themes were drawn to answer the research questions 3, 4, and 5.

Research Results

Anticipated Performance and Actual Achievements in Online Research Learning

The first research question was to find out what the SHS students' anticipated performance in online research learning is compared to their actual achievement. The results, as shown in Table 2, have revealed that among the students under HUMSS, those who attended synchronous modality research classes had a higher anticipated performance at the beginning of the semester, $\bar{x} = 5.36$, compared to their actual achievement at the end of the semester, $\bar{x} = 5.00$. Their asynchronous modality counterparts, on the other hand, had higher actual achievement, $\bar{x} = 4.97$, compared to their anticipated performance, $\bar{x}=4.38$.

Table 2
Comparison of Anticipated Performance with Actual Achievement in Online Research Learning

Strand	Learning Modality	Academic Achievement	$\bar{x}$	*SD*	Interpretation
Humanities & Social Sciences	SOL	Anticipated	5.36	0.67	Very Good
		Actual	5.00	0.00	Very Good
	AOL	Anticipated	4.38	0.78	Good
		Actual	4.97	0.16	Very Good
Accountancy, Business & Management	SOL	Anticipated	4.67	0.49	Very Good
		Actual	5.83	0.58	Excellent
	AOL	Anticipated	4.94	0.66	Very Good
		Actual	5.00	0.00	Very Good
Science, Technology, Engineering & Mathematics	SOL	Anticipated	4.91	0.64	Very Good
		Actual	5.14	0.55	Very Good
	AOL	Anticipated	4.61	0.70	Very Good
		Actual	4.91	0.34	Very Good
OVERALL	SOL	Anticipated	4.94	0.65	Very Good
		Actual	5.24	0.58	Very Good
	AOL	Anticipated	4.65	0.73	Very Good
		Actual	4.95	0.27	Very Good

5.50-6-Excellent
4.50-5.49-Very Good
3.50-4.49-Good
2.50-3.49-Satisfactory
1.50-2.49- Conditional Pass
1.0-1.49- Fail

Moreover, ABM students under synchronous modality have higher actual achievement, $\bar{x} = 5.83$, compared to their anticipated performance, $\bar{x} = 4.67$, whilst their asynchronous modality counterparts have a very small margin of difference between anticipated, $\bar{x} = 4.94$, and actual achievements, $\bar{x} = 5.00$.

Additionally, STEM students taking up synchronous modality research learning have an anticipated performance of $\bar{x} = 4.91$, lower than their actual achievement of $\bar{x} = 5.14$, similar to the data culled from their asynchronous modality counterpart with the anticipated performance of $\bar{x} = 4.61$, lower compared to their actual achievement of $\bar{x} = 4.91$.

Overall, students in both synchronous modality and asynchronous modality actually performed better than they had anticipated, although it is of note that students under synchronous modality generally have higher anticipated performance and actual achievement compared to their asynchronous modality counterparts.

Table 2 illustrates the paired differences among the different groups of SHS students' anticipated performance and actual achievement.

Table 2

Results of Paired Sample Test on Difference between Anticipated and Actual Achievement of SHS Students in Online Research Classes

	$\bar{x}$	*SD*	*t*	*p*	**Decision Rule**
Pair 1 AOL Anticipated – AOL Actual	-.299	0.76	-5.58	.0001	Reject the N_o
Pair 2 SOL Anticipated – SOL Actual	-.298	0.85	-2.86	.006	Reject the N_o
Pair 3 HUM SOL Anti – HUM SOL Actual	.366	0.67	1.78	.104	Fail to reject the N_o
Pair 4 ABM SOL Anti – ABM SOL Actual	-1.166	0.57	-0.79	.0001	Reject the N_o
Pair 5 STEM SOL Anti – STEM SOL Actual	-.227	0.77	0.007	.058	Fail to reject the N_o
Pair 6 HUM AOL Anti – HUM AOL Actual	-.589	0.75	-0.34	.0001	Reject the N_o
Pair 7 ABM AOL Anti – ABM AOL Actual	-.061	0.65	0.127	.518	Fail to reject the N_o
Pair 8 STEM AOL Anti – STEM AOL Actual	-.301	0.78	-0.157	.0001	Reject the N_o

Overall, a significant difference was observed in the anticipated performance ($\bar{x} = 4.65$) and actual achievement ($\bar{x} = 4.95$) of SHS students learning research under asynchronous modality with a p-value of .0001 at $\alpha = .05$. Likewise, a significant difference was also observed in the anticipated performance and actual achievement of SHS students learning research under synchronous modality with $p = .006 < \alpha = .05$.

However, within the strands, there were three pairs where no significant difference in anticipated performance and actual achievement was observed. These include the HUMSS strand under synchronous modality with a lower actual performance ($\bar{x} = 5.00$) compared their anticipated performance of $\bar{x} = 5.36$, a mean difference of 0.366 and p = .104. The second is the STEM strand under synchronous modality with a higher actual performance ($\bar{x} = 5.14$) compared their anticipated performance of $\bar{x} = 4.91$, a mean difference of -0.227 and a p-value = 0.058. Finally, the ABM strand under asynchronous modality with a very slightly higher actual performance ($\bar{x} = 5.00$) compared their anticipated performance of $\bar{x} = 4.94$, a mean difference of -0.061 and $p = .518$.

Conversely, there were also three pairs where a significant difference in anticipated performance and actual achievement in online research learning was observed. The first are ABM students under synchronous modality with an excellent actual performance ($\bar{x} = 5.83$) compared their anticipated performance of $\bar{x} = 4.67$, a mean difference of -1.166 and a p-value = 0.000. Likewise, HUMSS students under asynchronous modality with a very good actual performance ($\bar{x} = 4.97$) compared their anticipated performance of $\bar{x} = 4.38$, a mean difference of -0.589 and p = .000. Finally, STEM students under asynchronous modality with a higher actual performance ($\bar{x}$ = 4.91) compared their anticipated performance of $\bar{x}$ = 4.61, a mean difference of -0.301 and p = .0001.

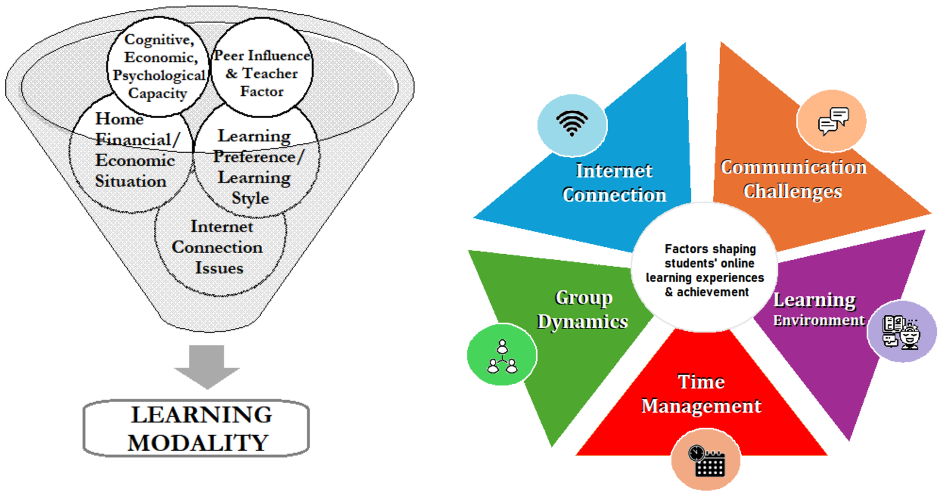
The disparities in how the groups of students performed may be explained by the factors that influenced their choice of learning modality and shaped their experiences in the online research classroom.

Factors Influencing Choice of Learning Modality

To better understand the disparities between the anticipated performance and the actual achievement of SHS students, the results of NViVo v. 10 and Clarke and Braun's thematic analysis protocol yielded *Internet connection issues* as one of the primary reasons behind the learner's choice. This is true for students under both asynchronous modality and synchronous modality, claiming that they have limited access to the internet, or that there are fluctuations in internet connectivity. Likewise, the students' *Learning preference/ Learning style* also contributed to their decision-making. Another significant theme that arose from the analysis of data is the students' *Home Financial or Economic Situation,* where siblings needed to share devices and laptops, and the kids share responsibilities and tasks at home. Additionally, students also took stock of their *Cognitive, emotional and psychological capacity* to manage the online research lessons and tasks. *Peer influence* and *Teacher-factor* also came out as themes shaping the students' decision on whether they will study online research under synchronous or asynchronous. Meanwhile, participants also identified several factors that shaped their online research learning experiences and achievements. After responses were analyzed using NViVo v. 10 and thematic analysis was performed, the data were coded and classified into five major themes – *Internet connection, Communication challenges, Learning environment, Time management, and Group dynamics*

Figure 1a illustrates the factors identified that have influenced students' choice of learning modality, while Figure 1b shows the factors that have shaped students' online learning experiences and achievement.

Figure 1



(a) Factors Influencing Students' Choice of Online Learning Modality

(b) Factors Shaping Students' Online Learning Experiences and Achievement

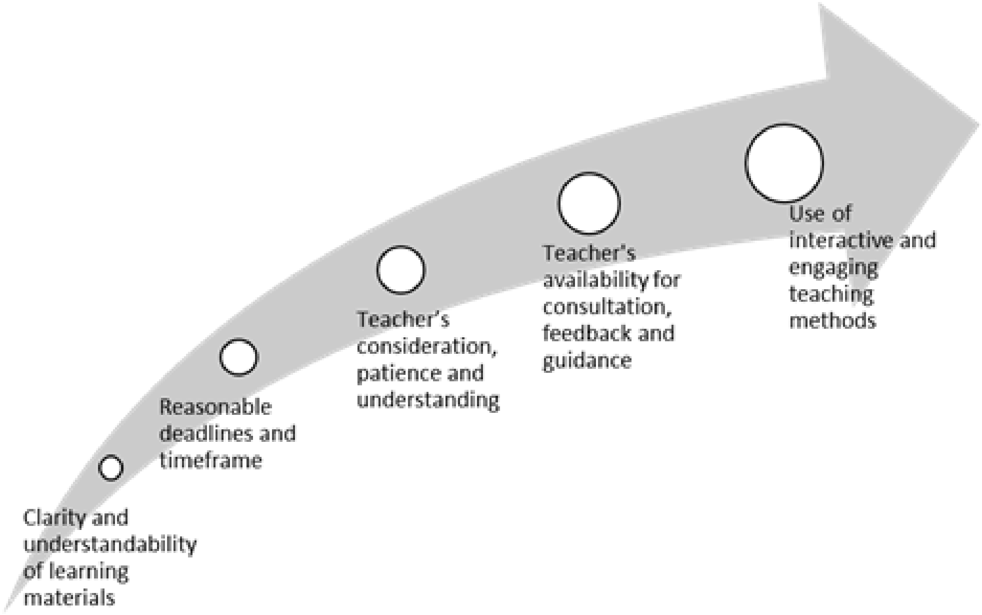
Cognitive, Economic, Psychological Capacity
Peer Influence & Teacher Factor
Home Financial/ Economic Situation
Learning Preference/ Learning Style
Internet Connection Issues
LEARNING MODALITY
Internet Connection
Communication Challenges
Factors shaping students' online learning experiences & achievement
Group Dynamics
Learning Environment
Time Management

Effective Teaching Practices in Online Research Learning

Based on the results, the participants of the study identified five teaching practices and strategies used by the research teacher that enabled the effective delivery of the research class in the online setting. The first theme identified is the use of c*lear and understandable learning materials* specially among Asynchronous students who navigate the materials independently. The second theme is *reasonable deadline and timeframes.* Since research requires submission of the different parts of the research project, giving ample time to work on the project was necessary. The third theme is the *teacher's consideration, patience, and understanding.* These teacher attitudes were identified to positively influence students' experiences and achievements in online research learning. Likewise, *teacher's availability for consultation, feedback, and guidance* were significant themes that contributed to students' learning. Finally, among students attending synchronous learning, the *use of interactive and engaging teaching methods* contributed positively to their learning experience.

Figure 2 shows how the identified themes contributed to enable students to progressively focus in online research learning toward the completion of their research project and achievement of the course objectives.

Figure 2
Teaching Practices and Strategies Utilized by Research Teachers in the Delivery of Online Research


Clarity and understandability of learning materials
Reasonable deadlines and timeframe
Teacher's consideration, patience and understanding
Teacher's availability for consultation, feedback and guidance
Use of interactive and engaging teaching methods

Discussion

The current study explores the anticipated and actual achievement of students in an online learning environment, the factors that influence their choice of learning modality and shape their experiences and achievement, as well as the effective teaching strategies used by the research teacher. The findings revealed that the students from different academic strands and learning modalities vary in their anticipated performance and actual achievement during the online research learning delivery. Specifically, students under the synchronous modality have higher anticipated performance and actually perform better than students under the asynchronous modality. With reference to previous studies, the results complemented the findings of the study of Nkoala and Matsilele (2021), stating that unequal access to technologies experienced by students results in unequal learning outcomes.

Overall findings on the factors that influence students’ choice of learning modality reveal several factors. Students’ responses suggest that internet connection issues remain largely a major factor both in choosing the learning modality and in shaping their experiences and achievement in online research learning. These results illustrate similarities with other studies (see Hodges et.al., 2020; Nkoala & Matsilele, 2021) indicating that those with more access to digital technologies and the internet influence the students in how they engage actively or passively in education to the point where they could or could not demonstrate responsibility, accountability, and their sense of autonomy. Moreover, those with more access derived more benefits (Nkoala & Matsilele, 2021). The data also suggests that students found it difficult to discuss the research project with groupmates online. Many students, both from synchronous and asynchronous, still iterated the need to have face-to-face interaction with their respective research collaborators. These results illustrate the need to create effective communication channels in an online learning environment as the lack of face-to-face interaction can become a hindrance to student engagement and collaboration (Means et al., 2010).

As shown in the data, since the students are studying at home, their diverse backgrounds and learning environments contributed to their experiences. The importance of a conducive home environment for learning is emphasized to set students up for success in a research online course (Derrick, 2003). Likewise, the data also suggest that time management influenced the experience of students in online research learning. One possible explanation for this is that some students may not have good self-regulation strategy in an online learning setting, while those who managed their time effectively were able to exhibit better outcomes. Another finding complemented studies by Graham (2002), Fung (2004), Häkkinen (2004), and Taylor (2005) which stated that group dynamics has a significant influence on students’ online research learning. Nevertheless, further studies are required to validate the impact of the home environment, time management, and group dynamics in the online research learning of students.

Nonetheless, the students identified a variety of teaching strategies that supported their online research learning experiences. For instance, the use of clear and easily understood learning materials, reasonable deadlines and timeframe, teacher’s consideration, patience, and understanding, teacher’s availability for consultation, feedback, and guidance, and the use of interactive and engaging teaching methods enabled the students to progressively focus and work toward the completion of their research project in the online setting. The varying teaching strategies confirmed earlier reports (see Kehward, 2008; Kwarteng, 2014; Ruzic et. al., 2021; Office of Educational Technology, 2017). The implications of these results illustrate the usefulness of learning materials to make learning more accessible for students so that they will be able to grasp concepts more easily (Kwarteng, 2014). Likewise, the significance of teachers’ affective actions toward students in online learning environments is also supported (Kehward, 2008). Another critical piece of information from the data is the significance of teacher’s availability for consultation, feedback, and guidance. The extent of availability of the teacher was not measured in the study though. Finally, the use of interactive teaching methods such as technology integration, use of gamification and other engaging tasks and activities advance the relationship between the teacher and students (Office of Educational Technology, 2017). Even so, further studies are required to validate the results.

Conclusion and Recommendations

In the context of the online research learning, based on the results, students in synchronous online research learning are more likely to have better anticipated performance and higher actual learning achievement compared to their counterparts undergoing asynchronous online research learning. This gap between the learning achievement of students under synchronous and asynchronous online research learning has been shaped by their choice of learning modality, influenced by their experiences and the teaching practices of the research teachers. Internet connection issues were primarily identified as a factor influencing the choice of learning modality and the experience of students that influenced their learning achievement. Other factors include communication difficulties, the students' learning environment at home, their capacity to manage time, and the group dynamics of the members of the collaborative research project where they belong. Moreover, teacher-factor was shown as a salient influence in students' online research learning experience, with the use of clear and comprehensible materials, flexibility of deadlines and timeframe, availability for consultation, and use of engaging teaching methods identified as integral practices and strategies that enable students to progressively focus and work toward the completion of their research project.

Given these results, it is recommended that in terms of online research learning instruction, the university work on policies and programs that will enable the equitable provision of access to internet resources for all students, especially the marginalized and underprivileged. Second, continuously provide faculty training on learning materials development and interactive and engaging research pedagogy, as well as the development of social and affective skills to build empathic relationships with students. Finally, with the global expansion of education mitigated by the internet and digital tools, advocating for international research collaborations among students and teachers of different local and international educational institutions may be more possible than ever. Thus, the creation of institutional partnerships and collaborations may be forged. Finally, for future researchers, the study may be replicated in other subject areas or disciplines among external campuses and colleges in the university to further establish, affirm or negate the results of the study.

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THE DEVELOPMENT AND INITIAL TESTS FOR THE PSYCHOMETRIC PROPERTIES OF THE EQUAL OPPORTUNITY IN EDUCATION SCALE

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Abstract

Although equality of opportunity in education is a current and important issue, most of the studies on this subject are based on theoretical studies rather than empirical studies. The main reason for this can be said to be the lack of a valid and reliable measurement tool in this field. For this reason, this study aims to develop a valid and reliable measurement tool for determining pre-service teachers' perceptions of equality of opportunity in education. For this purpose, data were collected from four different samples using a simple random sampling technique. First, a literature review was conducted, and qualitative interviews were conducted with the first sample on equal opportunities in qualitative education. After the item pool was created, the first application was made in order to determine the factor structure of the measurement tool. Data were collected from a separate sample to test the resulting structure and perform confirmatory factor analysis. Then, in the context of reliability studies of the measurement tool, calculation of the internal consistency coefficient, extracted mean variance, composite reliability and test-retest processes were used. As a result, a valid and reliable scale for determining the perception of equality of opportunity in education consisting of three factors and 23 items has been brought to the education literature.

Keywords: *equal opportunity in education, factor analysis, validity and reliability, scale development*

Introduction

Although some concepts seem to be understood in the literature, they are not fully clarified. The concept of equality, which is one of them, has been discussed for a long time, but its exact meaning has not been revealed. In his Defense (Phaedo), Socrates (1957), while discussing equality, did not dwell on what it means and did not try to make a definition. Rather, he emphasized the nature and intuitiveness of equality. In other words, he is more concerned with the application of the concept in principle rather than its definition. Contrary to Dworkin's (2002:142) statement that "people who praise or despise it cannot agree on what they praise or despise" to indicate that equality is a controversial and difficult concept, Socrates stated that equality is easy and understandable. If equality needs to be defined, it can be said that equality is having similar qualities in at least one aspect (Dann, 1975; Westen, 1990). In this respect, although the concept of equality is closer to "similar" than "same", there are sharp differences between them (Alsheh et al., 2013). For example, saying that two different groups of people are equal in something is not the same as saying that they are similar to each other. The concept of

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equality also emphasizes the differences between the things being compared. The absence of differences between the things being compared eliminates the need for the concept of equality. Because absolute qualitative equality leads to the concept of "same" (Tugendhat & Wolf, 1983).

Today, the concept of equality has become a tool used to combat discrimination based on race, gender, and ethnicity. Especially under the pressure of groups with feminist views, this concept is frequently used to support women (Bregant, 2014; Fineman, 2008; Rogošić et al., 2020). Dworkin's (2002) theory of equal distribution of resources and equal treatment of individuals is very difficult to apply in practice. This is because it is not possible to treat everyone equally since each person has different qualities compared to the other, i.e. some are smarter and some are less intelligent, some are hardworking, and some are lazy. Equality is not the equal distribution of wealth to everyone living in a country, but the ability to offer equal opportunities to each citizen. Equality also means that the state meets the basic needs of its citizens and provides equal opportunities according to their abilities. For this reason, sometimes treating and distributing wealth equally by ignoring individual abilities can lead to injustice. Equality emerged as a natural reaction to the fact that people are physically or mentally different. Equality is therefore based on the principle that differences should not be turned into discrimination and that no human being should be excluded.

The concept of equality is used in different ways in different places and times, which leads to confusion with other concepts. One of the most frequently confused concepts of equality is the concept of justice. While equality refers to discrimination and non-discrimination, justice is rather a state of judgment and value. Miller (1997) divided equality into two types and argued that the first type of equality is distributive according to justice and that rights should be distributed equally. The second type of equality, on the other hand, is not distributive and has nothing to do with the concept of justice, but rather refers to a society in which people do not discriminate against each other. Erdoğan (2008) also agreed with this idea and stated that equality, as a requirement or principle of justice, is one of the requirements of justice in a certain sense, although not in every sense. Barker (1951) stated that justice depends on the principle of freedom and freedom depends on the principle of equality. Therefore, although the concepts of equality and justice are similar in terms of some characteristics, there are relative differences between them.

There is no equality that emphasizes the physical and mental differences of the individual. This concept should be understood as equal social status and equal distribution of rights. Therefore, it would not be correct to say that equality cannot be found by emphasizing physical and mental differences. Gutmann (1995) stated that a state cannot apply full equality to its citizens of different races, ethnicities, religions, or genders. In this case, education has a major role to play and should foster mutual respect among citizens. In particular, it would be pointless to expect equality of opportunity only from the state and its full implementation.

Equality has different dimensions such as social equality, which means equal distribution of rights and opportunities; political equality, which gives everyone an equal share in public administration; economic equality, which means that wealth should be distributed more moderately by protecting the interests of weak people; legal equality, which stipulates that there should be no discrimination before the law; and international equality, which emphasizes that there should be no discrimination between states. While each of these concepts draws attention to a different aspect of equality, one of the most frequently used concepts related to equality is the discourse on equality of opportunity in education. The short definition of equal opportunity in education is that educational opportunities are accessible to everyone according to their abilities and interests (Aksu & Canturk, 2015). Brookover and Lezotte (1981) defined equality of opportunity in education as the guarantee that the state offers equal educational opportunities to all its citizens regardless of gender, race, perception, and economic conditions. In this context, it is also a matter of debate whether the privatization of schools will contribute to the reduction of discrimination among students (Anderson et al., 2019). Dovemark (2017) pointed out that privatization of schools will increase competition while also increasing inequality. According to Kubiatko (2023), inequality can cause students to become disinterested in school.

A large part of individuals' lives is spent in school. While education prepares individuals for the future, it also teaches them the skills, concepts, and virtues necessary for them to be free, equal, and responsible citizens (Neufeld, 2013). Being aware of one's rights and opportunities depends on receiving a good education because, educated individuals have more knowledge about citizenship rights and are more interested in the governance and future of the country than uneducated individuals (Verba et al., 2002). The importance of education for the individual and society is not open to debate. However, the issue of who has access to the rights and opportunities to receive high quality education is an important and debated issue.

The debate on improving the educational process is often conducted on the basis that children from different social strata should have the same educational conditions. This approach implies the equality of educational opportunities for children from various socio-economic groups (Froomkin, 1976). Although the discourse on equal opportunities in education is associated only with educational opportunities, in fact, this definition expresses only one aspect of the concept of equal opportunities in education. As a matter of fact, Campbell and Klein (1982) criticized those who emphasized only this aspect of equality of opportunity in education and stated that this concept cannot be limited to access to education and educational opportunities. For example, while Brookover and Lezotte (1981) examined existing education programs, they evaluated equality of opportunity in education only in the context of educational opportunities, resulting in an incomplete understanding of this concept. Equality of opportunity in education refers to a process that starts from the birth of an individual and does not pause as long as his/her education life continues. The inequalities that emerged among students in terms of technology and internet facilities in the distance education process during the coronavirus pandemic period constitute only one dimension of equality of opportunity in education.

Inequalities in the birth of a child; the opportunities in the country or place of birth, the educational status of his/her family, socio-economic levels, the sociocultural structure of the environment in which he/she grows up, the age at which he/she receives education, the equipment of the schools he/she attends, the competence of teachers, and many other reasons affect the opportunities of individuals to receive equal education. For example, it would not be correct to say that a child born in a poor village in Africa and a child born in a developed canton of Switzerland would have equal opportunities to receive education. When there are (natural) inequalities arising from the way human beings are born, states and legal bodies work to make people who are naturally unequal legally equal. When natural inequalities are combined with social inequalities, which Rousseau (1950) also mentioned in his Social Contract Theory, it is not possible to talk about students' equality of opportunity in education. Therefore, it is obvious that complete equality of opportunity in education cannot be achieved. However, it is possible to minimize inequality.

Today, it can be said that the development of technology and the internet have a positive effect on the solution of equality of opportunity in education. This is because the online lessons uploaded online by good teachers allow students, regardless of socioeconomic status, to access the lessons. Valdez (2004) stated that technological opportunities increase the accessibility of educational opportunities. Students who have access to computers and the Internet can access information more easily than other students. On the other hand, it is also possible to think that the development and affordability of technology trigger inequality of opportunity in education (Schofield & Davidson, 1998). In other words, scientific and technological developments open the door to new inequalities in education.

There are many studies in the literature on equal opportunities in education. Some of these have been observed to explore equality of opportunity in education from a historical perspective (Yen-Ting, 2018), conceptual perspective (Chand & Karre, 2019; Lazenby, 2016a; Shields et al., 2017; Shields, 2023; Shrage, 2017; Temkin, 2016a), from a political perspective (Maclean, 2003; Singh, 2014), from the perspective of the results of international exams (Schütz et al., 2005; Woessmann, 2004), from a democratic perspective (E. Anderson, 2007), and from a teacher training perspective (Watras, 2006). Most of these studies in the literature examined equality of opportunity in education from a theoretical perspective. The rarity of empirical research in the field shows that there are no valid and reliable measurement tools in this field.

Research Aim and Research Questions

This research aimed to develop a valid and reliable scale to empirically contribute to the issue of equality of opportunity in education. In the first stage of the study, the definition of equal opportunity in education and how it is understood by academic circles were focused on. Then, it was examined whether there were any quantitative studies in this field and whether there was a valid and reliable scale. At this stage, the item pool was created, and it was determined whether such a scale was needed. In the literature review, it was observed that there is no such scale and there is a need for a scale to measure the level of equality of opportunity in education. As a result of the research, a valid and reliable scale that will contribute empirically to the literature has been provided.

In addition, since scale development is a complex multi-step process, it was aimed to strengthen the field both theoretically and statistically by developing the scale of equality of opportunity in education in the hope of advancing the sociology of education research. In this context, the following research question was created:

- Can a valid and reliable tool be developed to measure the "perception of equal opportunity in education"?

Research Methodology

General Background

This study was designed in accordance with the quantitative approach of the positivist theory (Aliaga & Gunderson, 2002; Creswell, 2003; Gül, 2023a, 2023b). In addition, since scale development studies have an exploratory feature depending on their purpose (Carpenter, 2018), this study was carried out in accordance with the nature of scale development studies. The study was designed, and data were collected in the 2021-2022 academic year. It was aimed to develop a measurement tool regarding equality of opportunity in education. The validity and reliability of the scale were tested with statistical analyses performed on the collected data.

Sample

The study was conducted on four different samples consisting of university students in the spring semester of the 2021-2022 academic year. The first sample consisted of 17 primary school teachers. This sample was used to enrich the item pool by conducting qualitative interviews. Yamane's (1967) formula was used to determine the sample size for the data to be collected for EFA and CFA. This formula is as follows:

$$n= N/(1+N(e)^2$$

Where N is the population size, n is the sample size, and e is the level of precision. When this formula is applied to the study universe, we get the following equation:

$$n= 5000/(1+5000(.05)^2 = 370$$

According to Yamane's formula, the number of samples must be at least 370. In this study, the total of both samples is 651. For this reason, the sample size of the study was deemed sufficient. According to Fabrigar et al. (1999), the samples determined for EFA and CFA should be different from each other. For this reason, different samples were used for EFA and CFA in the study. An attempt was made to reach a sufficient sample size to apply EFA to the second application data. In the literature, researchers (McCrosky & Young, 1979; Worthington & Whittaker, 2006) recommend a sample size of over 300 for EFA. Therefore, the second study group consisted of 356 students, 266 (74.7%) of whom were female and 90 (25.3%) of whom were male, from 3 different universities. The third sample consisted of a total of 295 university students, 227 (42.4) women and 68 (12.7) men. Since CFA will be performed on the data obtained from this sample, the number of samples was deemed sufficient because CFA requires a smaller sample size than EFA (Kyriazos, 2018; Tabachnick & Fidell, 2007). Additionally, the statistical power and precision of a CFA model parameter estimates are affected by the sample size (Brown, 2015), whereas in CFA a hypothetical model is tested. In the fourth application, the measurement tool was administered twice for two weeks to 30 people consisting of 22 women and 8 men.

Exploratory Factor Analysis (EFA) was conducted on the data obtained from the application with the first sample, and Confirmatory Factor Analysis (CFA) was conducted on the data obtained from the application with the second sample. Then, a different third study group was used to measure the stability of the measurement tool. However, it may be more difficult to administer the EOSE twice to the same sample group within a certain time interval than administering it once. For this reason, test-retest reliability analyses were conducted on a smaller third study group.

Table 1
Study Groups Participating in the Research

Study Groups	Scale Applied	Statistical procedures	
First Study Group	Interview form	Interviews were conducted with this sample group to enrich the pool of items expected to measure the perception of equality of opportunity in education.	
Second Study Group	Scale (EOSE)	Ensuring construct validity and applying EFA	Calculation of Cronbach's Alpha reliability coefficient over the data set resulting from the combination of the first and second study groups
Third Study Group	Scale (EOSE)	Performing CFA to test construct validity and calculating composite reliability coefficients	
Fourth Working Group	Scale (EOSE)	Calculating the correlation between the first and second application for test-retest reliability between measurements	

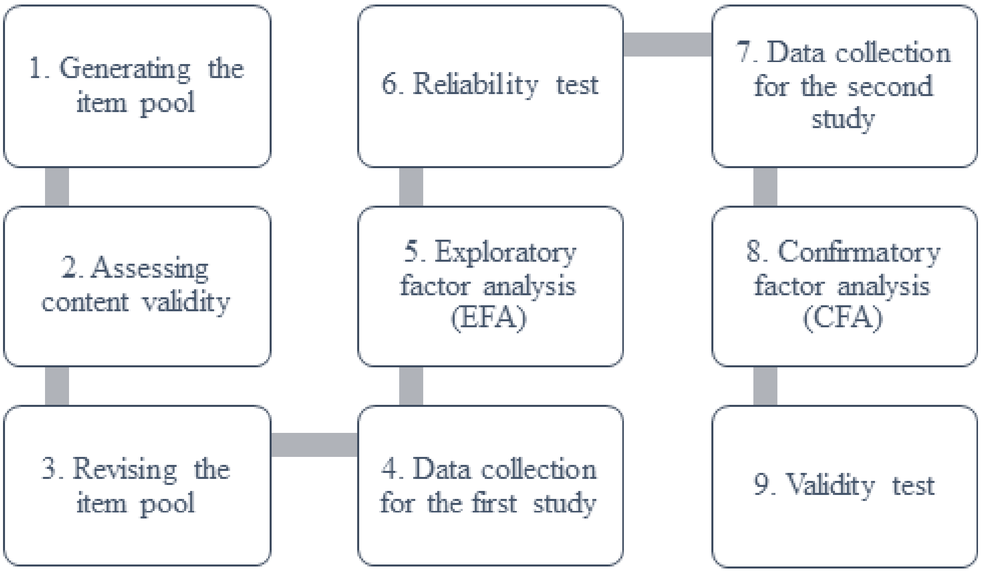
Data Analysis

Development of the item pool and form for the development of the Equal Opportunity in Education Perception Scale (EOSE) and the validity and reliability analyses are presented. While content validity and construct validity were utilized within the scope of the validity of the measurement tool, Cronbach's Alpha internal consistency reliability, average variance extracted (AVE), composite reliability (CR), item analysis and test-retest techniques were utilized within the scope of reliability analysis. The scale has 3 sub-dimensions and 23 items in total. The maximum score that can be obtained from the scale designed as a 7-point Likert scale is 91, while the minimum score is 23. The first sub-dimension of the scale is named as Familial Factors, the second sub-dimension as Geographical-Social Factors, and the third sub-dimension as Administrative Factors. A high score in the sub-dimensions of the scale emphasizes that the perception of that sub-dimension is negative, while a low score emphasizes that the perception of that sub-dimension is positive. In other words, since all of the scale items consist of negative statements, the total score obtained in each sub-dimension indicates that the perception of equality of opportunity in education is negative, while a low score indicates a positive perception.

Research Results

Each stage of the research process depicted in Fig. 1 significantly contributes to establishing the validity and reliability of the EOSE. The sequential approach for developing the measurement instrument comprises nine key steps: (1) generating the item pool, (2) assessing the content validity of the item pool via expert panel reviews, (3) revising the item pool, (4) collecting data for the first study, (5) performing exploratory factor analysis (EFA), (6) reliability test, (7) collecting data for the second study, (8) conducting CFA, and (9) performing a validity test. Figure 1 outlines the general path to follow in the process of developing the measurement instrument. The process begins with the creation of scale items. In order to create the item pool, the literature was first reviewed, and domestic and international studies on equality of opportunity in education were examined. As a result of the literature review, a pool of 27 items was created. While determining the statements to be included in the item pool, care was taken to ensure that they were in a way to exemplify all possible qualitative content in the light of other known alternative assumptions about equality of opportunity in education because the item pool should be more comprehensive than the theoretical framework in the target area (Clark & Watson, 1995). According to Fabrigar et al. (1999), an important factor may not occur if the researcher inadequately samples the variables in the relevant field. Therefore, in order to enrich the item pool, a group of 17 primary school teachers were asked about their opinions on equal opportunity in education. A semi-structured form consisting of 6 questions was prepared to obtain teachers' opinions. The interview form included questions such as: what do you understand when it comes to equality of opportunity in education, do you think that rich people receive better education than those who are poorer than them, etc. In line with the opinions of the teachers, the number of statements in the item pool increased from 27 to 42.

Figure 1
The Process of Developing a Measurement Instrument


1. Generating the item pool
2. Assessing content validity
3. Revising the item pool
4. Data collection for the first study
5. Exploratory factor analysis (EFA)
6. Reliability test
7. Data collection for the second study
8. Confirmatory factor analysis (CFA)
9. Validity test

Content Validity

In order to ensure the content validity of the created item pool, it was given to 4 faculty members from the fields of Measurement and Evaluation, Psychological Counseling and Guidance, Curriculum Development and Educational Philosophy from the field of Educational Sciences to evaluate the items in terms of representing the feature to be measured. Davis's (Davis, 1992) technique was utilized in the evaluation of content validity and expert opinion form. According to this technique, expert opinions are evaluated as (a) the item represents the characteristic, (b) should be corrected a little, (c) should be corrected a lot, and (d) the item does not represent the characteristic. The sum of the a and b values in the forms received from the experts is divided by the number of experts to calculate the content validity index. Items where this value is more than 0.80 are considered to be sufficient in terms of content validity, while items below this value are removed from the form. Accordingly, as a result of the expert feedback, 5 items with a value less than 0.80 were removed from the scale, leaving 37 items in total. In addition, the agreement percentages of the forms received from the experts were calculated as 91%.

In order to conduct validity and reliability analyses of the scale with the remaining items in the scale form, a pre-application form was created before it was applied to the target group. The scale was designed as a 7-point Likert scale with the following options: "Strongly Disagree", "Disagree", "Somewhat Disagree", "Neither Agree nor Disagree", "Agree", "Somewhat Agree" and "Strongly Agree". For the scoring of the scale items, each option was given a number from 1 to 7, starting with "Strongly Disagree". The scale was then administered to a group of 48 university students to determine whether the items were understood and whether there were any difficulties in understanding. In addition, the total score of each student was calculated based on the duration of the administration of the scale. As a result of the pilot application, the process of transforming the scale into an appropriate format that facilitates statistical procedures and prevents confusion was completed.

Construct Validity

EFA and CFA tests were applied to test the construct validity of the data obtained from the EOSE, respectively. In the application of EFA and CFA and using ML (maximum likelihood) as a parameter estimation technique, it is assumed that the observed variables have a multivariate normal distribution (Bayram, 2016; Kılıç, 2019). In the studies conducted in the field of Social Sciences, these values were examined since the understanding of whether the data have normal distribution characteristics is mostly provided by Skewness and Kurtosis values. According to some researchers (Field, 2009; George & Mallery, 2010) the presence of these values between +2 and -2 is accepted as sufficient evidence that the data fulfill the normality distribution condition. Since the kurtosis (-.443 - 1.683) and skewness (-.019 - 1.949) values of each of the observed variables in this study were between +2 and -2, it was assumed that the data had a multivariate normal distribution.

Exploratory Factor Analysis (EFA)

EFA is conducted to test whether there is an order among the responses of the respondents to the items of the scale being developed (Tavşancıl, 2002) and to determine the factor structure of the measurement tool. Prior to EFA, the KMO value was calculated as 887 and Bartlett's test results were statistically significant (χ^2 = 2171.603, *SD* =253). As a result of the first EFA, an 8-factor structure explaining 54.65% of the total variance was reached (Table 2). However, it was determined that there were items that formed factors alone or with two items. The items that formed a factor with a single item or two items and the items that had loading values in more than one factor were removed from the measurement tool. Then, in the repeated EFA, a 3-factor structure explaining 50.60% of the total variance was obtained as a result of the direct oblimin rotation technique (delta=0, kappa=4) due to its factorization technique and factor relationships (Carpenter, 2018).

Table 2
Factor Structure and Factor Loadings of EOSE

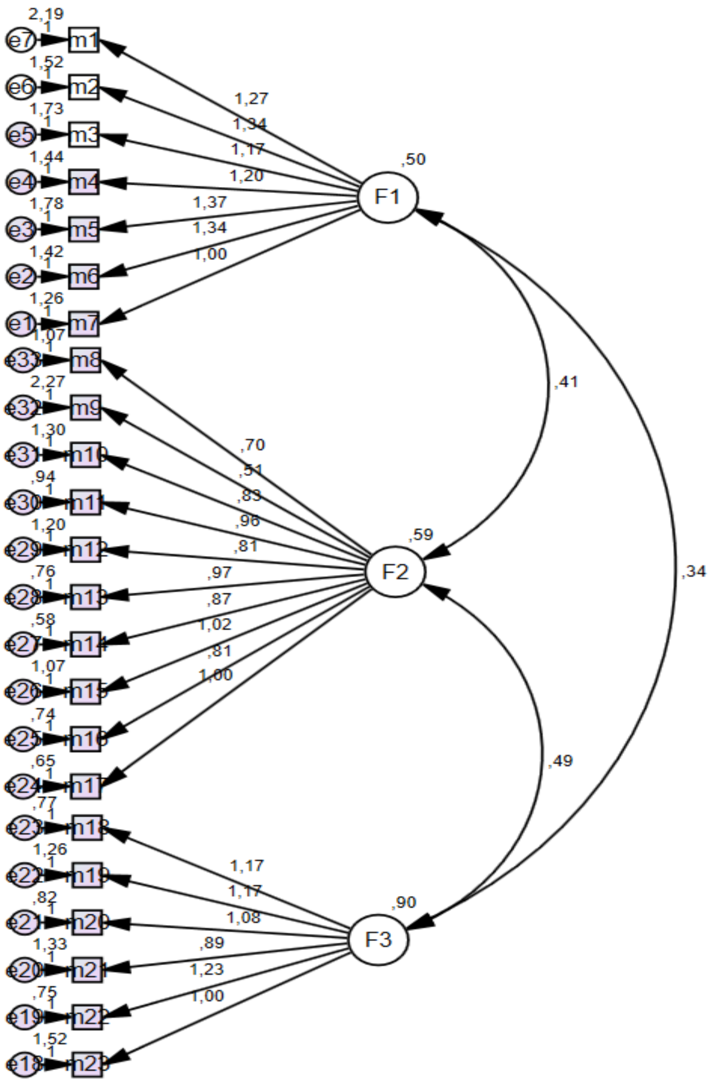
Item No	**Factor Loadings**		
	Factor 1	**Factor 2**	**Factor 3**
M7	.755		
M4	.712		
M2	.707		
M1	.664		
M6	.552		
M5	.460		
M9	.456		
Variance Explained	**9.791**		
M20		.704	
M17		.686	
M24		.627	
M18		.620	
M19		.598	
M25		.534	
M30		.529	
M15		.521	
M29		.516	
M16		.482	
Variance Explained		**32.176**	
M32			.739
M33			.682
M36			.684
M34			.606
M37			.587
M35			.513
Variance Explained			**8.640**
Total Variance Explained		**50.60**	

Confirmatory Factor Analysis (CFA)

CFA was applied to determine whether the data obtained as a result of the application on the second sample group confirmed the structure consisting of 23 items and 3 factors obtained after EFA.

Figure 2

Standardized Factor Loadings Obtained as a Result of CFA



The fit index values of the EOSE were calculated as $\chi^2/SD = 2.71$, GFI = .90, AGFI = .88, CFI = .90, NFI = .85, PNFI = .77, IFI = .90, RMSEA = .057, RMR = .097, PNFI = .76 and PGFI = .74. The factor loadings of the three-dimensional model obtained after CFA ranged between .52 and .61 in the first factor, .25 and .69 in the second factor, and .59 and .80 in the third factor, respectively.

Reliability Studies

Within the scope of the reliability studies of the measurement tool, internal consistency coefficient calculation, average variance extracted, composite reliability, test-retest and item analysis procedures were included.

Cronbach Alpha, average variance extracted (AVE), composite reliability (CR) and test-retest methods were used to test the reliability of the measurements made with the EOSE. The Cronbach Alpha reliability coefficient of the measurement tool was calculated as .890 for the overall scale. The AVE and CR reliability values of the scale are calculated based on the factor loadings obtained from CFA. Their formulas are as follows:

$CR = (\sum\lambda)^2/[(\sum\lambda)^2 + \sum(1- \lambda^2)]$

$AVE = \sum\lambda^2/n$

It is recommended to calculate AVE and CR values, especially in scale development studies (Hair et al., 2009). In order for the Cronbach Alpha and CR values calculated for the measurement tool to be accepted as reliable, the AVE value should be calculated as ≥0.70 and ≥0.50 (Table 3) (Claes & Larcker, 1995).

Table 3
Test Results for Scale Reliability

Subscales	Cronbach Alpha	CR	AVE	Test-Retest
Factor 1	.768	.72	.86	82
Factor 2	.800	.94	.55	86
Factor 3	.855	.70	.71	81

Discriminant Validity

In order to determine the predictive and discrimination levels of the items in the EOSE, the comparison of the 27% lower and upper groups was made. As a result of the analysis, the t value between the lower and upper groups of the scale was calculated as 14.86 (SD = .286, $p < .05$) significant. In scale development studies, a significant t value for the difference between the lower and upper groups is accepted as evidence for the discrimination of the scale in the measured construct (Erkuş, 2012). Based on these results, it can be said that the scale has the feature of discrimination between low and high scores of equality of opportunity in education.

Discussion

In this study, it was aimed to develop a valid and reliable measurement tool to determine the perception of equality of opportunity in education. For this purpose, firstly, an item pool was created as a result of literature review and teacher interviews, and then the content validity of the draft form was ensured in line with expert opinions. Some researchers (Cohen & Swerdlik, 2018; Slaney, 2017) define content validity as determining how representative the scale items are to measure target behaviors. According to Thorndike and Hagen (1961), content validity reveals the relevance of the prepared items to the measured structure. For this reason, Rubio et al. (2003) stated that researchers should receive constructive feedback during the scale development process while ensuring content validity. Fitzpatrick (1983) pointed out that expert opinions alone are not sufficient to ensure content validity, and that there must also be a scoring based on quantitative data. For this purpose, Davis technique was used in this study, and expert opinions were scored.

After ensuring content validity, the first application was carried out to determine the factor structure of the scale. Considering the compatibility of KMO and Bartlett tests for exploratory factor analysis of the data set, EFA was applied, and the three-factor structure of the measurement tool was reached because, in scale development, it is recommended that EFA be applied first, considering the possibility of researchers to be mistaken about scale dimensionality (Carpenter, 2018). Looking at the scales developed to measure psychological constructs in the literature, it is observed that approximately 70% of them include sub-dimensions (Clark & Watson, 1995). In order to test the accuracy of the three-factor structure, CFA was conducted on the data obtained from a new sample group. Studies in the literature (Costello & Osborne, 2005; Kline, 2013; Worthington & Whittaker, 2006) recommend using a separate sample group for CFA. As a result of CFA, it was understood that the fit index values were adequate.

It is thought that the development of such a scale in the field of education will contribute to increasing the number and quality of empirical studies in the field of equality of opportunity in education. The analyses carried out during the scale development process are proof that the measurement tool produces accurate measurements. Additionally, this study provides rich theoretical information for understanding equality of opportunity in education. According to Lazenby (2016), it is not clear what educators and politicians mean when they say they are in favor of equal opportunities in education. Using similar expressions, Temkin (2016) pointed out that equality of opportunity in education has many faces. This study was conducted to draw a framework for equality of opportunity in education and also to develop a scale to measure perceptions and attitudes on this issue.

Conclusions and Implications

The study includes validity and reliability studies of the scale being developed. Within the scope of reliability studies, the Cronbach Alpha internal consistency coefficient was calculated, and it was observed that this value was at a good level. Within the scope of reliability studies, AVE average variance was extracted, and CR composite reliability coefficients were also calculated. It was determined that the CR and AVE values calculated based on the factor loadings obtained from CFA were at a sufficient level. Then, the test-retest technique was used to check whether the measurement tool made stable measurements. As a result of this process applied on a separate sample group, the correlation value between the tests was found to be sufficient. Finally, an independent samples t-test was performed on the data between the lower and upper groups to determine the discrimination feature of the measurement tool, and the difference was found to be significant.

As a result, a valid and reliable measurement tool consisting of 23 items with three sub-dimensions was developed. A high score on the scale emphasizes that the perception of equal opportunity in education is negative and a low score emphasizes that it is positive. Since the scale development process is a complex and multi-step process, researchers need to pay great attention. The Equality of Opportunity in Education Scale was developed as a result of a process in which the researchers handled each step with great seriousness and attention. This scale has made a contribution by examining the concept of equality of opportunity in education and providing a scale to this field. One of the important issues to be considered here is that the construct measured is exploratory and the resulting measurement is open to development over time. The measurement results should be brought to the attention of not only educational researchers but also policymakers.

Ethical Statement

This research was conducted with the permission of Kyrgyzstan Turkey Manas University Scientific Research and Publication Ethics Committee with the decision numbered 8146 dated 01/06/2022.

Author Conflict of Interest Information

There is no conflict of interest between the authors.

Author Contribution

The first author: wrote the methodology and the results of the validity and reliability studies.
The second author: wrote the theoretical framework and item pooling.

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Appendix 1. Draft-Item Pool

	Equal Opportunity in Education Belief Scale
1	The education that children with higher socioeconomic status receive is more qualified than those with lower socioeconomic status.
2	Private schools provide more qualified education than public schools.
3	The state cannot provide necessary education to children with poor socioeconomic status.

4	In terms of teacher qualifications, teachers in urban areas are in a better situation than teachers in rural areas.
5	School facilities vary depending on the residential area (village, district, province) where the school is located.
6	The excess number of students per teacher in rural schools has a negative impact on the quality of education.
7	The number of schools is not sufficient in rural areas.
8	Children of poor families cannot receive as good an education as children of rich families.
9	Well-educated families are more interested in their children's education.
10	Families with different levels of education also have different interests in their children's education.
11	Children with a higher socioeconomic status have a greater say in the governance of the country because they receive a good education.
12	Qualified teachers are assigned to big cities.
13	The education received by children growing up in different sociocultural environments is also different.
14	No matter how intelligent students in rural areas are, the environment they grow up in prevents them from using their intelligence.
15	I think that the state cannot provide equal opportunity in education.
16	I think that economic inequalities in society are also reflected in education.
17	I think having fee-paying schools increases inequality.
18	The geography the student lives in affects the quality of the education he receives.
19	In order to learn a foreign language in the country I live in, the economic situation must be good.
20	Students with low socioeconomic status cannot benefit equally from distance education opportunities.
21	Women cannot receive as good education as men.
22	Students in rural areas cannot access sufficient educational materials.
23	It is difficult to discover the talents of children with low socioeconomic status.
24	I think applying the same education program to everyone causes inequality.
25	The versatile upbringing of children (language, sports, music, etc.) varies according to socioeconomic levels.
26	I think that many of the children who commit crimes turn to crime because they cannot receive a good education.
27	Teachers do not treat every student equally in the classroom.
28	I think the central exams are unfair.
29	I think that equality of opportunity cannot be achieved in education.
D30	The fact that children have to work while studying has a negative impact on their education.
31	Schools should help students with low socioeconomic status.
32	I think every child who receives quality education will be successful.
33	The attention shown to students varies depending on the teacher.
34	The city where the school the student attends affects the quality of the education he receives.

35	The profession of the student's family affects the quality of the education he receives.
36	The student's access to educational materials depends on the effectiveness of the school administrator.
37	I think that the economic power and opportunities of the country I live in are not distributed equally for the education of individuals in the same age group.
38	There are people who cannot obtain education opportunities simply because their socioeconomic level is low.
39	I think that the scope and quality of the national exams held in the country I live in do not provide equal opportunity in education.
40	In the country I live in, the share allocated to the education of children in need of special education is lower than the share allocated to the education of other children.
41	I think that the country I live in has not made enough efforts to create an appropriate mechanism to distribute opportunities equally.

Appendix 2. Final version of instrument

		Equal Opportunity Scale in Education
Family Factors	1	Since children of families with higher socioeconomic status receive better education, they have a greater say in the governance of the country.
	2	The education that children of families with higher socioeconomic status receive is more qualified than those of those with lower socioeconomic status.
	3	I think one of the most important variables when it comes to dealing with children's education is the education level of the family elders.
	4	The socioeconomic level of the family is decisive in discovering children's talents.
	5	In order for children to develop in all aspects (language, sports, music, etc.), it is necessary for families to have good socioeconomic levels.
	6	The profession of the student's family elders is a determining variable in the quality of the education they receive.
	7	Students with low socioeconomic status cannot equally benefit from distance education opportunities in out-of-school settings.
Geographic-Social Factors	8	It is impossible to ensure justice and peace in societies where equality of opportunity cannot be achieved.
	9	I think that many of the children who commit crimes turn to crime because they cannot receive a good education.
	10	There are people who cannot obtain education opportunities simply because their socioeconomic level is low.
	11	The education received by children growing up in socioculturally different social environments (city, neighborhood, village, etc.) is also different.
	12	The fact that children have to work while studying has a negative impact on their education.
	13	An important reason for inequalities in education is the existence of economic inequalities in society and in the country.
	14	School facilities vary depending on the residential area (village, district, province) where the school is located.
	15	The excess number of students per teacher in rural schools has a negative impact on the quality of education.
	16	The economic and social opportunities of the settlement where the school is located strongly affect the quality of education provided in schools.
	17	There are significant inequalities in terms of the number of teachers in rural or urban areas.

Administrative Factors	18	I think that the state has not been able to create the necessary mechanisms and regulations to ensure equality of opportunity in education.
	19	I think that the central exams conducted by the state do not provide equal opportunities.
	20	I think that the economic power and opportunities of the country I live in are not distributed equally for the education of individuals in the same age group.
	21	In the country I live in, the "average" share allocated to the education of children in need of special education is lower than the "average" share allocated to the education of other children.
	22	I think that the country I live in has not made enough efforts to create an appropriate mechanism to distribute opportunities equally.
	23	I do not believe that opportunities such as scholarships, loans, transportation support and housing for disadvantaged groups are distributed in a way that provides balance.

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IDENTIFYING AND VALIDATING SUSTAINABLE DEVELOPMENT GOALS-RELATED KEY COMPETENCIES IN UNDERGRADUATE GRAPHIC DESIGN EDUCATION

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Abstract

In contemporary higher education, aligning student competencies with sustainable development goals (SDGs) is crucial for enhancing their employability. This necessity extends to graphic design undergraduate programs, pivotal in nurturing designers capable of addressing global sustainability challenges. Using a mixed-methods approach, this study aims to outline essential competencies for graphic design undergraduates pertinent to the SDGs. The research commenced with a systematic review of fourteen seminal articles, leading to the initial identification of fifty-eight key competencies. Subsequently, a Delphi study involving 44 graphic design experts validated these competencies. This iterative process refined the list, excluding twenty-seven competencies and affirming thirty one as critical. These validated competencies were categorized into four groups: Systemic, Performance, Contextual, and Global. The study's findings provide valuable insights for graphic design educators and industry employers, illuminating competencies essential for addressing sustainability challenges. Furthermore, this research contributes to academic discourse by offering a structured framework for integrating SDG-related competencies into graphic design education. This facilitates the development of designers proficient not only in their craft but also in sustainability imperatives. Our aim is to enhance pedagogical strategies and inform curriculum development in graphic design education, aligning them with evolving professional demands and sustainable development objectives.

Keywords: *key competencies, SDG, design education, sustainability, Delphi method, systematic review, graphic design*

Introduction

In contemporary higher education, the imperative for institutions to train students with competencies that align with sustainable development (SD) has been increasingly recognized as critical for enhancing their employability, responsiveness to sociocultural shifts, and adaptability to technological progress. This has been particularly salient in undergraduate design education, where the traditional paradigms of design practice have been critically reevaluated in light of the exigencies of sustainable societal transformation (Manzini et al., 2001). The evolving landscape has necessitated the cultivation of designers' competencies not only in aesthetic and functional innovation but also equipped to address the multifaceted challenges of sustainability (Vezzoli & Manzini, 2008).

Agenda 2030's focus on sustainability (UN, 2015) highlights resource management's importance, making circular economy a key solution (Ellen MacArthur Foundation, 2012). Though its definition evolves (Korhonen et al., 2018), core principles like closed-loops are shared by cradle-to-cradle design and industrial ecology (Graedel & Allenby, 1995; McDonough & Braungart, 2002). The Ellen MacArthur Foundation's influential definition positions CE as an economic system focused on restoration and regeneration (2012).

SDG 12, "Responsible Consumption and Production," is a pillar of the UN's 2030 Agenda for Sustainable Development (UN DESA, n.d). It aims to shift global consumption and production patterns towards sustainability, recognizing the environmental and societal harm caused by current practices in developed nations. By promoting responsible choices by individuals and corporations, SDG 12 fosters a healthier planet and a sustainable global economy.

Over 20 years ago, the World Academies of Science made a strong statement urging that science and technology be used to drive a global shift towards sustainability (IAP, 2000). Despite technological advancements, progress towards sustainability is hampered by deficient global education. Education, especially in science and social sciences, underpins innovation and economic productivity. It equips individuals to navigate a changing job market, securing employment and improving their quality of life. The scientific community plays a vital role. Natural and social sciences must be the core curriculum, and collaboration between scientists and educators is crucial for engaging science education. Scientists are united in their calls for urgent changes to human activities in order to halt the degradation of the natural environment (Ripple et al., 2020).

Shifting legal, market, and financial pressures push manufacturers to develop and market sustainable products. Product life cycle impacts depend on interactions with social, economic, and technical systems. Businesses, especially established ones, can drive change through design and communication (Gutterman, 2023)

Community engagement is vital for service design to drive social innovation. Designers bring specific skills to co-create solutions with communities, addressing local challenges and opportunities (Manzini & Jégou, 2008). Understanding this context is key, as successful service design requires a human-centered, transformative approach (Karpen et al., 2017)

Spangenberg et al. (2010) argued design is crucial for achieving satisfaction with sustainable practices. They propose that design's full potential is unlocked only through a sustainability lens (p. 1492). This suggests educating designers in sustainability principles is essential to fulfilling design's philosophy, mirroring the circularity found in nature for millennia. Moreover, the discipline of design for sustainability has emerged, and as Vezzoli et al. (2018) write “in its broadest and most inclusive meaning could be defined as a design practice, education, and research that, in one way or another, contributes to sustainable development.”

Design education in the 21st century necessitates a critical reevaluation to prepare future designers for a dynamic and multifaceted landscape. This transformation must encompass not only an aptitude for evolving technologies but also a profound understanding of social issues, human behavior, and contemporary business models. Furthermore, designers must navigate novel ethical challenges arising from expanding into diverse global territories with distinct sustainability concerns, cultural contexts, and value systems (Meyer & Norman , 2020).

The findings of this study have implications for both graphic design educators and employers. This article contributes to knowledge in two ways: (1) synthesize and systematize results from previous studies on the competencies of designers needed in the new context and challenges of sustainability; (2) key competencies required that undergraduate students studying design must possess to meet the challenges of Systemic challenges, Performance challenges, Contextual challenges and Global challenges. This research is important for design schools, educators, as well as design students. It clarifies what is desired and achievable by clearly identifying which competencies are appropriate for each individual.

The significance of this research extends beyond academic discourse and offers pragmatic insights for graphic design educators and industry employers. By elucidating the competencies required for sustainability-focused design practice, this study contributes to the redefinition of design education, advocating for a curriculum that not only equips students with the technical and creative skills pertinent to their discipline but also imbues them with the knowledge and values essential for fostering sustainability. Thus, this research plays a crucial role in shaping the future of design education, ensuring that the next generation of designers is prepared to meet the challenges of a rapidly evolving and increasingly complex global landscape.

Literature review

Evolving Paradigms of Sustainable Development: An Imperative for Design

Since the 1970s, concerns about resource depletion and environmental degradation have spurred the rise of Sustainable Development (SD). Early works like Malthus's population theory (Coomer, 1979) and Meadows' "Limits to Growth" (1972) highlighted resource constraints. Later, Daly (1992) and Basiago (1996) emphasized managing growth and environmental concerns. Today, SD encompasses economic, social, and environmental dimensions, aiming for balance and equity (Taylor, 2016). Key challenges include resource constraints, pollution, and climate change (Basiago, 1996, 1999). Mounting evidence necessitates a fundamental shift in human behavior towards sustainability. This demands reevaluating underlying assumptions, beliefs, and frameworks that guide our actions (Rieckmann, 2017). Recognizing the interconnectedness with nature, humanity, and the wider impacts of individuals' actions is crucial (Department of Economic and Social Affairs - UN, 2016).

From Eco-Design to Sustainable Development Goals: A New Directive for Designers

The emergence of *Design for Environment* (Fiksel, 1995) and *Eco-Design* (Brezet & Hemel, 1997) represents a pivotal shift towards embedding sustainability across product life-cycles. This shift, while monumental, is but a precursor to the larger and more ambitious goals outlined in the United Nations Sustainable Development Goals (SDGs). These goals, particularly as analyzed by Kanie and Biermann (2017), extend an open invitation—and indeed, a challenge, to the design community: to innovate within the constraints of sustainability, to redefine problem solving through a sustainable lens, and to actively contribute to the global sustainability agenda.

Education in Change: The Role of Sustainable Design

Central to realizing the vision of sustainable design is the overhaul of design education itself. The emphasis of the 2030 Agenda on Education for Sustainable Development (ESD), as encapsulated by SDG4, heralds a new era of design pedagogy. This transformative education, as advocated by UNESCO (2017), is not merely about imparting knowledge but about fostering a generation of designers who are critical thinkers, problem solvers, and sustainability champions. The collaborative networks and partnerships mentioned by Mulà et al. (2017) exemplify the collective effort needed to embed ESD within design curricula globally.

Competency-Based Education: Bridging the Gap Between Theory and Practice

The dialogue on "competency" in design education, inspired by pioneers like Hamel and Prahalad (1994) signals a departure from traditional educational models towards a more dynamic, skills-oriented framework. However, this competency-based approach necessitates a radical rethinking of curriculum design to address the "Performance", "Systemic", “Contextual” and "Global" challenges of contemporary design practice, as critiqued by Friedman (2019). The current state of design education, while making strides towards sustainability, often falls short in equipping students with the comprehensive skill set required to navigate and influence the complex, interconnected systems of the modern world.

This review underscores an urgent need for a paradigmatic shift in design education toward sustainability, recognizing the integration of SD principles into design curricula not as an option but as a moral imperative. In the face of global environmental challenges, the design community is called upon to adopt a transformative educational model that equips future designers with the required knowledge, skills, and critical thinking abilities. The journey ahead is fraught with challenges but offers a unique opportunity to redefine the essence of design in forging a sustainable future. This narrative, shaped by both historical and contemporary analyses, serves as a clarion call for a necessary evolution in design education, setting a new course towards sustainability.

Research Methodology

General Background

This research embarked on a nuanced exploration of the essential competencies required by designers to navigate the evolving landscape of sustainability challenges. Adopting a mixed-methods methodology, the study meticulously combined secondary and primary data sources to attain a holistic understanding of the competencies that align with sustainability standards. Thus, this study began with a systematic review of the literature, carefully analyzing 14 seminal articles to distill 58 critical competencies deemed essential for contemporary design challenges (Step 1). Subsequently, a Delphi study was employed involving 44 experts - comprising 32 academic scholars and 12 industry professionals - to validate these competencies, ensuring the validity (Step 2).

Step 1: A Systematic Review of Previous Studies

The employment of systematic analysis in this study represents a bibliometric exploration of the extant literature, aiming to identify influential trends and seminal works within the domain of design education and sustainability. This step aims to explore bibliometrics indicators like citations, keywords, authors and so on. Such an approach has been utilized in numerous disciplines, notably in "business, management, and accounting," "economics, econometrics, and finance," and "social sciences" (Broadus, 1987; Pritchard, 1969; Wallin, 2005).

Specifically, using the Web of Science and Scopus databases, we conducted a search query using related keywords as follows: *21st century, design education, competency framework, circular economy, and sustainable development* with the aim of collecting the initial data. Thus, 628 documents were obtained at this step. Next, the researchers read thoroughly the abstracts of these 628 documents in order to identify the papers focusing specifically on designer competencies for sustainable development. After this step, 42 documents were identified. Next, another round of screening of these 42 documents was adopted as we read carefully the full texts of these 42 documents. Eventually, we obtained 14 documents which would be used for systematic content analysis (see Table 1). The aim of content analysis is to figure out a list of 58 competencies necessary for sustainable graphic designers. These 58 competencies were grouped into four types of challenges faced by sustainable graphic designers according to (Meyer & Norman, 2020) (see Table 4).

Table 1
List of Key Papers On Graphic Designer Competencies For Sustainable Development

No	Authors	Title	Journal	Year of publication
1	Simon O'Rafferty, Hannah Curtis and Frank O'Connor	Mainstreaming Sustainability in design education – a capacity building framework	International Journal of Sustainability in Higher Education	2014
2	Watkins M., Casamayor J.L., Ramirez M., Moreno M., Faludi J., Pigosso D.C.A.	Sustainable Product Design Education: Current Practice	She Ji: The Journal of Design, Economics, and Innovation	2021
3	Sumter D., de Koning J., Bakker C., Balkenende R.	Key Competencies for Design in a circular economy: Exploring the gaps in design knowledge and skills for a circular economy	Sustainability	2021
4	Freitas A.P.N.D., Almendra R.A.	Soft skills in design education, identification, classification, and relations: proposal of a conceptual map	Design and Technology Education: An International Journal	2021
5	Noël G.	Fostering Design Learning in the Era of Humanism	She Ji the Journal of Design Economics and Innovation	2020
6	Weil D., Mayfield M.	Tomorrow's Critical Design Competencies: Building a Course System for 21st Century Designers	She Ji: The Journal of Design, Economics, and Innovation.	2020
7	Meyer, M.W., Norman, D.	Changing Design Education for the 21st Century	She Ji: The Journal of Design, Economics, and Innovation.	2020
8	Sumter D., de Koning J., Bakker C., Balkenende R.	Circular economy competencies for design	Sustainability	2020
9	Ostergaard T.	Decoding Sustainable Competencies and didactics in design education	The 22nd International Conference on Engineering and Product Design Education	2020
10	Moreira M.	Making Design Education (Even More) Complex: Exploring Complexity for an Amplified Mindset of Design	The International Journal of Art & Design Education	2019
11	Haug A.	Educating ethical designers	International Journal of Technology and Design Education	2017
12	Casais M., Christiaans H., Almendra R.	Sustainability curricula in design education	International Conference on Engineering and Product Design Education	2012
13	Wiek A., Withycombe L., Redman C.L.	Key competencies in sustainability: A Reference Framework for academic program development	Sustainability Science	2011
14	Trimingham, R., Lofthouse, V., Norman, E., Bhamra, T., Zanker, N.	An integrated approach to sustainable design education	International Conference on Engineering and Product Design Education	2008

Step 2: A Delphi Study

Panel Selection

Critical to the Delphi technique's efficacy is the deliberate selection of an expert panel, tailored to address questions characterized by high levels of uncertainty and speculation (Okoli & Pawlowski, 2004). The process of participant selection is paramount, influencing the study's relevance and success significantly (Clayton, 1997; Franklin & Hart, 2007; Gordon, 2003; Skulmoski et al., 2007). An "expert" within this context is someone endowed with the requisite knowledge and experience to contribute meaningfully to the Delphi process (Clayton, 1997).

For this study, 44 experts in the field of Design, comprising 32 lecturers and 12 education experts, with 68.2% possessing experience ranging from 6 to over 20 years, were invited to participate in the Delphi rounds. This diverse panel was selected to gather a broad spectrum of insights and experiences related to curriculum development, teaching methodologies, and management within design education and its emerging challenges and trends. Communication with experts was facilitated via email, and responses were collected through an online platform.

These 44 experts were recruited in a convenient manner as all of them are colleagues of one of the co-authors of this paper. According to McKenna (1994), in the Delphi study, the panel of experts is recommended to have close connections with researchers in order to ensure high retention after successive rounds. Initially, 70 eligible experts were invited to join the study, and 44 of them agreed. According to Endacott et al. (1999), the number of participants in a Delphi study should be between 20 and 50. Thus, our number of 44 experts is satisfactory.

Consensus Process

The study achieved consensus after two rounds of the Delphi process. The first round involved interviews with 44 experts, while the second round saw the participation of 39 experts. Thus, 88.6% of experts responded in both rounds, indicating a high level of engagement and consensus across the pool of participants (see Table 2).

This rigorous application of the Delphi study underscores its utility in synthesizing expert insights to inform the identification and validation of key competencies required for designers in the contemporary professional and academic setting. The method's systematic approach to soliciting and refining expert judgments provides a robust foundation for developing competency-based educational strategies aligned with current and future demands in the design sector.

Table 2

Profile of Experts in Two Delphi Rounds

	Round 1		Round 2		All rounds *	
	f	*%*	*f*	*%*	*f*	*%*
Professional experience (years)						
< 5	14	31.8	13	33.3	13	29.5
06_10	14	31.8	12	30.8	12	27.3
11_15	7	15.9	6	15.4	6	13.6
15_20	5	11.4	5	12.8	5	11.4
> 20	4	9.1	3	7.7	3	6.8
Highest educational degree						
Doctor of Philosophy (PhD)	5	11.4	3	7.7	3	6.8
PhD Candidate	2	4.5	1	2.6	1	2.3
Master (MA)	33	75.0	31	79.5	31	70.5
Bachelor	4	9.1	4	10.3	4	9.1
Profession						
Lecture	32	72.7	29	74.4	29	65.9
Education Expert	12	27.3	10	25.6	10	22.7
University/ Organization/ Company						
University	44	100	39	100	39	88.6
Organization	0	0	0	0	0	0
Company	0	0	0	0	0	0

Note. All rounds *represent participants who responded to all two Delphi rounds.

Statistical Measures Employed

The primary statistics utilized in Delphi studies encompass measures of central tendency and dispersion, specifically standard deviation and interquartile range. These measures are essential to depict the consensus and diversity of opinions within the respondent group (Hasson et al., 2000). The median and mode are often preferred for their ability to represent the central position of ratings in a non-normally distributed data set, which is common in Delphi studies. The literature strongly supports the use of the median score, particularly with Likert-type scales, to ascertain the intensity of expert agreement or disagreement on a linear continuum (Eckman, 1983; Hill & Fowles, 1975; Hsu & Sandford, 2019; Jacobs, 1996).

Likert-Type Scale Application

Likert-type scales, assuming a linear intensity of experiences ranging from strong agreement to strong disagreement, are widely adopted to measure attitudes within Delphi studies. For instance, a 4-point Likert scale ranging from *Very Important* (4) to *Not Important* (1) is commonly used to gauge expert perceptions. Green (1982) posits that a consensus threshold should be established where at least 75% of participants rate level 3 or 4-point Likert scale, with a median score requirement of 3.25 or higher to indicate agreement.

Stability and Consensus Measurement

Scheibe et al. (1975) argued against the sufficiency of percentage measures alone, advocating for the assessment of response stability across successive rounds as a more reliable indicator of consensus. Stability, or the convergence of panel responses, is achieved when minimal shifts occur from one round to the next, suggesting a reaching of consensus (Murry & Hammons, 1995).

To facilitate this analysis, rating scales are converted to numerical values, and the mean and standard deviation are calculated, excluding non-responses. Typically, a 75% agreement threshold is recommended for consensus on items by the second round or subsequent rounds. The literature does not provide any rigid standards for the consensus, however, every study should define what percentage of the participants' responses will be considered consensus (Murry & Hammons, 1995).

Table 3
Rules For Analyzing The Ratings From Multiple Experts With Delphi Approach

Round t for Delphi questionnaire	Round t + 1 for Delphi questionnaire	Round t + 2 for Delphi questionnaire
Rating_Mean(*qi*) >= 3.25	IF Rating_Mean(*qi*)>= 3.25 and % f(3/4) represents >= 75%, Then *qi* is accepted, and no further discussion concerning *qi* is needed	
Rating_Mean(*qi*) < 3.25	IF Rating_Mean(*qi*)<3.25 and % f(3/4) represents < 75% Then *qi* is rejected, and no further discussion concerning qi is needed	
Rating_Mean(*qi*) < 3.25	IF Rating_Mean(*qi*)<3.25 and % f(3/4) represents >= 75%	Rating_Mean(*qi*) >= 3.25 and Rating_Variant(*qi*) < 15% and f(3/4) represents >= 75% Then *qi* is accepted, and no further discussion concerning *qi* is needed

Source: Green (1982)

Research Results

Results from Systematic Analysis

Following 14 key papers as presented in Table 1, an in-depth reading and analysis of each article were undertaken to identify the essential competencies for sustainable graphic designers. Thus, 58 competencies were figured out and grouped into four challenges (Performance, Systematic, Contextual, and Global) as shown in Table 4.

Table 4
List of Competencies for Sustainable Graphic Designers Extracted from Literature Review

Code	Competency
A	Performance challenges
A1	Creativity
A2	Critical thinking
A3	Anticipatory competency
A4	Negotiation skill
A5	Commitment to lifelong learning
A6	Leadership
A7	Self-direction/ Self-management
A8	Teamwork
A9	Ethics/compromise
A10	Entrepreneurship
A11	Legislation and regulatory compliance
A12	Visual and verbal communication
A13	Sketching, Modeling, Prototyping, Simulation skills
A14	Designing for multiple use cycles
A15	Sustainable product design methods/ process
A16	Dematerialization, design/component simplification
A17	Research and Exploration
A18	Circular economy understanding
A19	Circular economy communication
A20	Circular business model integration
A21	Understanding cost implications
B	Systemic challenges
B1	Systems thinking and Holistic thinking
B2	Circular systems thinking
B3	Systemic understanding/ System innovation
B4	Knowledge of materials and manufacturing processes
B5	Understand new contexts for design and innovation
B6	Engineering-related knowledge of how the product functions
B7	Failure mode and effects analysis (FMEA) and maintenance methods
B8	Understanding of user behavior, user testing and ethnography
B9	Interdisciplinary design
B10	Design of product-service systems (PSS)
B11	Design of digital circular logistics systems

B12	Design simplifies complicated system perception and description
C	Contextual challenges
C1	Problem solving
C2	Risk taking
C3	Adaptability in work
C4	Decision making and trade-offs in design processes
C5	Empathic user-focused understanding & observation
C6	Data-driven design may help policy and action.
C7	Circular user engagement
C8	Service design process
C9	Circular (reversed) logistics cost and organization
C10	Understand key concepts of sustainable development, including social aspects
C11	Reverse logistics & logistics - supply chain, manufacturing, repair
C12	Understanding of the commercial, institutional, legislative, and social motivations for implementing sustainable development.
C13	Understanding of the concept of sustainable design and how it exists within an industrial context.
C14	The capability to collaboratively analyze complex systems across diverse domains and various scales
C15	Understand how to analyze the environmental profile of a product and generate appropriate improvement options
D	Global challenges
D1	Conscious of environmental, social, cultural, and human issues.
D2	Circular impact assessment
D3	Eco-materials knowledge
D4	Understanding low carbon and resource efficiency
D5	Methods and tools to assess environmental impact: life cycle analysis (LCA)
D6	Eco-design/sustainable product design strategies and application
D7	Understand how to analyze the environmental profile of a product and generate appropriate improvement options
D8	Circular economy and 3R implementation (reduce, reuse, recycle)
D9	Design for X (e.g. recycling, disassembly, re-use, remanufacture)
D10	Have an appreciation of the commercial, institutional, legislative, and social motivations for implementing Sustainable Development.

Results of the Delphi Technique

Delphi Round One

Table 5 delineates the initial assessment of 58 competencies in four challenges, attributing a mean (*M*), Standard Deviation (*SD*), and a categorization outcome - *Accepted, Next Round* or

Rejected - based on expert ratings. These ratings were quantified using a 4-point Likert scale, ranging from *Very Important* (4) *to Not Important* (1), to gauge the relative importance of each competency, according to the expert's opinion.

Table 5
Results of Delphi's Round 1

Challenges	Code	*M*	*SD*	% *f*(3/4)	Results of Round 1
Performance challenges	A1	3.70	0.5	100	Accepted
	A2	3.57	0.5	98	Accepted
	A3	3.11	0.7	84	**Next Round**
	A4	3.25	0.7	93	Accepted
	A5	3.48	0.6	98	Accepted
	A6	**2.82**	**0.8**	**61**	**Rejected**
	A7	3.41	0.7	89	Accepted
	A8	3.25	0.8	82	Accepted
	A9	3.59	0.5	98	Accepted
	A10	**2.61**	**0.8**	**55**	**Rejected**
	A11	3.48	0.7	91	Accepted
	A12	3.45	0.7	91	Accepted
	A13	3.43	0.6	95	Accepted
	A14	3.25	0.6	91	Accepted
	A15	3.25	0.7	86	Accepted
	A16	**2.95**	**0.7**	**77**	**Next Round**
	A17	3.52	0.6	93	Accepted
	A18	**2.86**	**0.7**	**66**	**Rejected**
	A19	2.75	0.7	68	Rejected
	A20	2.64	0.6	57	Rejected
	A21	3.00	0.7	77	Next Round
Systemic challenges	B1	3.52	0.6	98	Accepted
	B2	**2.80**	**0.7**	**73**	**Rejected**
	B3	3.25	0.7	93	Accepted
	B4	3.39	0.8	86	Accepted
	B5	3.36	0.7	91	Accepted
	B6	**2.98**	**0.7**	**73**	**Rejected**
	B7	**2.89**	**0.7**	**70**	**Rejected**
	B8	3.57	0.6	93	Accepted
	B9	**3.11**	**0.8**	**82**	**Next Round**
	B10	**2.98**	**0.6**	**80**	**Next Round**
	B11	**2.82**	**0.6**	70	Rejected
	B12	3.00	0.7	73	Rejected

Contextual challenges	C1	3.68	0.5	98	Accepted
	C2	**2.86**	**0.7**	**75**	**Next Round**
	C3	3.45	0.7	93	Accepted
	C4	3.25	0.7	86	Accepted
	C5	3.48	0.6	93	Accepted
	C6	2.80	0.6	73	Rejected
	C7	2.89	0.7	75	Next Round
	C8	2.91	0.7	73	Rejected
	C9	2.80	0.7	**73**	**Rejected**
	C10	3.27	0.7	89	Accepted
	C11	**2.86**	**0.6**	**72**	**Rejected**
	C12	3.25	0.7	93	Accepted
	C13	3.43	0.6	93	Accepted
	C14	**2.77**	**0.6**	**66**	**Rejected**
	C15	3.30	06	95	Accepted
Global challenges	D1	3.48	0.6	93	Accepted
	D2	**2.93**	**0.6**	**80**	**Next Round**
	D3	**3.23**	**0.7**	**84**	**Next Round**
	D4	**2.80**	**0.8**	**59**	**Rejected**
	D5	**2.91**	**0.7**	**74**	**Rejected**
	D6	3.34	0.7	89	Accepted
	D7	**2.93**	**0.7**	**73**	**Rejected**
	D8	3.25	0.6	93	Accepted
	D9	3.27	0.6	93	Accepted
	D10	**3.07**	**0.8**	**73**	**Rejected**

Note: $N = 44$. Mean *(M)* and Standard Deviation *(SD)* are calculated for a 4-point Likert scale. % *f*(3/4) represents the percentage of respondents rating 3 or 4 on a 4-point Likert scale.

The first Delphi round precipitated a discernible diversity in the assessment of competencies, as evidenced by a spread in mean scores from 2.61 to 3.70. In particular, the competency C*reativity* (*A1*) emerged as paramount, receiving the highest value at 3.70, juxtaposed against *Entrepreneurship* (*A10*), which was evaluated as the least critical, with a score of 2.61.

Of the 58 identified competencies, the consensus was reached on 30, which were subsequently endorsed for this phase. Within this group, 23 competencies were particularly prominent, obtaining scores above 3.4, indicative of a consensus that exceeded 90%. On the contrary, the other 19 competencies did not achieve the requisite consensus for advancement due to their inability to meet the dual criteria delineated in Table 3: specifically, a mean score falling below 3.25 coupled with fewer than 75% of experts giving a score of 3 or 4-point score.

This dichotomy in expert consensus, which approximates 84.5% (49/58 competencies) endorsed or dismissed - underscores a significant alignment among the 44 participating experts in their assessment of competencies. A residual 15.5% of the competencies remained contentious, meeting the criterion of a supermajority exceeding 75% for the top two ratings, yet faltering on the mean score benchmark of 3.25. These nine competencies earmarked for further scrutiny in subsequent Delphi rounds reflect the iterative nature of achieving scholarly consensus.

The initial Delphi round unveiled divergent perspectives among experts on the relative importance of key competencies, with a marked preference for those associated with innate creativity and talent in the design realm. For example, unanimity was observed in the assessment of C*reativity* (A1) competency, with a resounding score of 3.4. This trend continued with high valuations for competencies related to *Sketching, Modeling, Prototyping, Simulation* skills (A13) at 95%, *Design for X (e.g. recycling, disassembly, re-use, remanufacture)* (D9) at 93%, and *Visual and verbal communication* (A12) at 91%.

In addition, competencies that facilitate cognitive development, such as *Critical thinking (A2)* and *Systems thinking and Holistic thinking (*B1), received near-universal acclaim, reflecting a consensus on their indispensable role in contemporary design practice. This recognition extends to competencies enhancing cross-disciplinary understanding and adaptability, underscoring their importance in navigating job-specific demands and future shifts within the field.

Competencies integral to sustainable design also received significant expert endorsement, signifying a collective recognition of their centrality to industry practices. This is exemplified by robust support for *Sustainable product design methods/processes* (A15) at 86%, an *Understanding of the concept of Sustainable Design and how it exists within an industrial contex*t. *(C13)* at 93%, and strategies for *Eco-design/sustainable product design strategies and application* (D6) at 89%.

Interestingly, the competency associated with L*eadership* (A6) was comparatively undervalued, with a mean score of 2.82 and 61% of top-level ratings, culminating in its exclusion in the initial round. This decision aligns with the sector's prioritization of *Teamwork* (A8), which was affirmed by an 82% approval rating, illustrating the nuanced considerations inherent in curating competencies for the evolving landscape of design education and practice.

Delphi Round 2

In accordance with the iterative nature of the Delphi method, competencies not reaching consensus in the initial round were given further scrutiny in the subsequent round. This second phase of the evaluation engaged 39 experts, representing 88.6% of participation as delineated in Table 2, thus satisfying the criteria for the requisite number of expert participants established in Round 1.

Table 6
Results of Delphi's Round 2

Challenges	Code	*M*	*SD*	% f(3/4)	Results of Round 2
Performance challenges	A3	3.13	0.7	79	Rejected
	A16	3.05	0.8	79	Rejected
	A21	2.97	0.9	74	Rejected
Systemic challenges	B9	3.18	0.8	79	
	B10	3.03	0.6	85	Rejected
Contextual challenges	C2	3.08	0.8	82	Rejected
	C7	3.00	0.6	82	Rejected
Global challenges	D2	2.82	0.7	67	Rejected
	D3	3.26	0.7	87	Accepted

* *Note. N* = 39. The mean (*M*) and standard deviation (*SD*) are calculated for a 4-point Likert scale. % f (3/4) represents the percentage of respondents who rate 3 or 4 on a 4-point Likert scale.

An analytical review of the data presented in Table 6, juxtaposed with the findings in Table 5, indicated a pronounced consistency in the assessment of competencies in the two rounds. Despite observable fluctuations in the rating variable (*qi*) between competencies, the aggregate mean scores remained predominantly stable. A nuanced analysis aimed at deciphering the evolution of the ratings of each expert between the two rounds was carried out. The results, cataloged in Table 7, detail the expert reviews in Round 2. Of particular note was the competency in e*Eco-materials knowledge* (*D3)*, which uniquely registered an increase in its mean score, surpassing the stipulated benchmark of >= 3.25 to achieve a mean of 3.26 and satisfying the Rating Variant criterion (*qi*) criterion of <15%.

In the context of the percentages assigning ratings of 3 or 4 on a 4-point Likert scale, a solitary competency, *Circular Impact Assessment* (*D2*), demonstrated a regression below the threshold level, with % f(3/4) recorded at 67%. Consequently, after the completion of two Delphi rounds, a total of 31 key competencies were ratified as having satisfied all evaluative criteria and thus were endorsed. On the contrary, 27 key competencies were adjudicated as not meeting the requisite standards and were therefore excluded from further consideration. These determinations are encapsulated in the *Final Result* section of Table 4. The study was brought to a conclusion at the end of Round 2, following the achievement of a consensus among the panel of experts.

Table 7

Analysis of the ratings in the two rounds of ratings given by the Panel of Experts

Code	Round	Ratings given by expert				($\bar{x}$)	% *f*(3/4)	Rating Variant (qi) %
		f(1)	*f(2)*	*f(3)*	*f(4)*			
A3	Round 1	0	7	25	12	3.11	84	**23**
	Round 2	0	8	18	13	3.13	79	
A16	Round 1	1	9	25	9	2.95	77	**28**
	Round 2	2	6	19	12	3.05	79	
A21	Round 1	0	10	24	10	3.00	77	**28**
	Round 2	3	7	17	12	2.97	74	
B9	Round 1	2	6	21	15	3.11	82	**23**
	Round 2	1	7	15	16	3.18	79	
B10	Round 1	0	9	27	8	2.98	80	**18**
	Round 2	0	6	28	5	2.97	85	
C2	Round 1	2	9	26	7	2.86	75	**38**
	Round 2	2	5	20	12	3.08	82	
C7	Round 1	1	10	26	7	2.89	75	**13**
	Round 2	0	7	25	7	3.00	82	
D2	Round 1	0	9	29	6	2.93	80	**33**
	Round 2	0	13	20	6	2.82	67	
D3	Round 1	0	7	20	17	3.23	84	13
	Round 2	0	5	20	14	3.26	87	

Discussion

This study rigorously explores the essential design competencies required to effectively address the multifaceted challenges of sustainability in graphic design education. It underscores the pivotal role of foundational skills such as creativity, critical thinking, and effective communication, which are indispensable for both problem-solving and persuasive communication within the domain of graphic design (Thornhill-Miller et al., 2023). These competencies are highlighted as crucial for enabling designers to innovatively and empathetically tackle sustainability challenges, thereby promoting a shift from traditional, rigid design methodologies to more flexible, problem-oriented approaches. Importantly, the research advocates for a balanced educational framework that integrates solid design competencies with a robust understanding of sustainability principles. This is essential to prepare students not only to engage creatively but also to act effectively within the sustainability context. The study aligns with existing literature that emphasizes the necessity of a broad grasp of social, environmental, and commercial dynamics to successfully navigate the complexities of sustainable design (Swanson, 2020; Deniz, 2016).

The curriculum's emphasis is on cultivating a fundamental comprehension of key sustainability concepts such as the circular economy, eco-materials, and the broader impact of design choices, rather than a deep specialization in tools like circular logistics or detailed sustainability analysis. This approach reflects a strategic educational shift towards building versatile problem-solving skills over narrow technical proficiencies, which might be more relevant to specific, specialized roles within the field. This prioritization of generalist over specialist skills is corroborated by studies suggesting that while specialized knowledge can be crucial, the versatility of foundational skills often provides a stronger base for addressing diverse design problems (Fass et al., 2018).

Furthermore, the study indicates a notable preference for teamwork over leadership skills within the curriculum, possibly reflecting the collaborative nature of contemporary design practices and the overlapping competencies between leadership and critical thinking. This curriculum design ensures that graduates are equipped with a comprehensive skill set that is adaptable to a variety of design scenarios, even at the cost of sacrificing depth in certain specialized areas. It would be beneficial to evaluate the effectiveness of this revised curriculum in preparing graduates to confront real-world sustainability challenges in their professional practices. Such studies could further refine our understanding of the balance between foundational and specialized competencies in design education, particularly in the context of sustainable practices.

In conclusion, this study contributes to the ongoing discourse on design education by delineating a clear educational pathway that balances design competencies with sustainability principles, ensuring that future designers are well-prepared to contribute meaningfully to the global sustainability agenda.

Conclusions, Implications and Limitations

This study delved into the crucial competencies emphasized within graphic design education, particularly how these competencies align with the overarching needs of the design industry and contribute to addressing systemic sustainability challenges. The study identified high-consensus competencies such as creativity, critical thinking, visual and verbal communication, and prototyping. These are affirmed as aligning well with core design requirements and underscore the necessity of equipping students with robust tools for creative problem-solving and effective communication, fundamental across a spectrum of graphic design roles.

Further, the study delineated a specific set of core competencies: systems thinking, holistic thinking, understanding of materials and manufacturing processes, and user-centered design principles as critical for tackling systemic challenges. The deliberate exclusion of overly specialized skills underscores the importance of foundational knowledge across diverse design roles, suggesting that broad, versatile skill sets may be more beneficial than highly specialized competencies in the current educational landscape.

Theoretically, this study enriches the academic discourse by systematically compiling and organizing existing research on designer competencies related to sustainability. It elucidates critical competencies necessary for graphic design students to successfully navigate the challenges within identified domains, thereby contributing significantly to the literature.

Practically, the outlined competencies serve as a strategic guide for both educational institutions and industry. For educators, this scaffolding informs pedagogical strategies and curriculum development, aiming to cultivate designers well-versed in sustainability and adept in their craft. For the industry, this competency framework can guide talent acquisition, ensuring that new hires possess the requisite skills to thrive in dynamic design environments and contribute meaningfully to sustainability.

Despite its insights, this study acknowledges several limitations. The systematic review was confined to fourteen key papers, potentially limiting the breadth of competencies identified. The insights from 44 experts, while valuable, may not encompass the full spectrum of global design community perspectives. These constraints suggest the need for further research involving a broader array of literature and a more diverse and extensive panel of experts to enhance the robustness and applicability of the findings.

Additionally, the study did not explore specific pedagogical strategies that could be most effective in developing these competencies among graphic design students. Future research should investigate instructional designs and curriculum frameworks that effectively nurture these essential skills, aligning educational programs with both market demands and sustainability imperatives.

In sum, this study provides a foundational understanding of the competencies essential for graphic design students to contribute effectively to sustainability goals and excel in the modern job market. It lays the groundwork for future research to expand methodological approaches and pedagogical strategies, which is crucial for refining and advancing our understanding of how best to prepare designers for the challenges of sustainable development and professional practice.

Declaration of Interest

The authors declare no competing interest.

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THE EFFECTS OF POLYA'S PROBLEM SOLVING WITH DIGITAL BAR MODEL ON THE ALGEBRAIC THINKING SKILLS OF SEVENTH GRADERS

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Abstract

There is a dearth of empirical data to support the positive effects of problem solving (PS) combined with digital technology in the classroom, despite claims that these activities improve students' algebraic thinking abilities. Therefore, the purpose of this study was to evaluate how the teaching method known as Polya's problem solving with digital bar model (PSDMB) affected the seventh graders' ability to think algebraically. Ralston's framework, which covers Generalised Arithmetic, Function, and Modelling within the topic of Linear Equation, served as the foundation for the evaluation of algebraic thinking abilities. A quasi-experimental pre-test and post-test control group design was employed. A total of 90 seventh graders, aged twelve- to thirteen-year-olds, from a secondary school in Tambunan, Sabah, Malaysia, made up the sample. Three teaching groups were formed out of these randomly chosen students: PSDMB (n = 30), Bar Model (MB) (n = 30), and Conventional Problem Solving (CPS) (n = 30). Both the pre- and post-algebraic thinking tests were taken by students. The post-test results were analysed using MANCOVA with the students' pre-test results acting as covariates. The results indicated that students in the PSDMB group performed notably better in Generalised Arithmetic, Function, and Modelling than those in the MB group, who, in turn, outperformed those in the CPS group. These results imply that incorporating digital bar model into problem-based learning is a successful strategy for improving seventh graders' algebraic thinking abilities.

Keywords: *algebraic thinking skills, digital bar model, Polya's problem solving, seventh graders*

Introduction

For students to be prepared to solve mathematical problems, algebraic thinking abilities are essential. These issues require more than just the simple application of formulas or algorithms; instead, they call for critical and creative thinking. To find solutions, students need to be able to analyse problems, think creatively, and use a variety of problem-solving techniques. Multiple ways to solve non-routine problems are frequently available, which fosters a deeper comprehension of mathematics and improves students' problem-solving skills (Mamat & Wahab, 2022). Additionally, students preparing for college coursework and jobs require algebraic thinking skills. However, the Trends in International Mathematics and Science Study (TIMSS) results show that Malaysian students' proficiency in algebraic thinking skills for problem-solving is still below the intended benchmark (Mullis, 2017). Just 5% of students in Malaysia, which is ranked 29th out of 42 participating countries in TIMSS, are able to apply, reason, and generalise when solving algebraic problems. One of the main obstacles to learning non-routine problem solving, according to Stacey (2005), is that students need a wide

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variety of skills in order to solve these kinds of problems. Consequently, educating students in problem-solving is considered a demanding undertaking (Dendane, 2009). According to Reiss and Renkl (2002) and Novotná (2014), heuristic strategies are deemed valuable for enhancing non-routine problem-solving skills. Heuristic solutions, in Pólya's (1945) view, are concerned with understanding the successive steps that lead to successful resolutions of problem situations, especially the mental processes that are involved in making connections, associations, and comparisons during the problem-solving process. Based on Polya's work, this heuristic approach consists of four distinct stages: understanding the problem, coming up with a plan of action, carrying out the selected strategy, and lastly, assessing and fine-tuning the solutions obtained. The heuristic problem-solving approach in algebra education focuses on teaching and learning algebraic concepts through activities that are closely connected to particular contextual settings. This means tackling real-world issues that might not be immediately obvious or simple due to their complexity.

Literature Review

Learning Environment for Developing Algebraic Thinking Skills

Diversifying teaching strategies for algebraic topics is crucial for fostering students' algebraic thinking skills (Blanton & Kaput, 2003; Blanton et al., 2019a, 2019b). The emphasis on student-centred approaches in 21st-century education has led to the perception that conventional teaching methods are insufficient. Ramsden (1992) and Anthony and Walshaw (2009) suggested that quality teaching requires a systematic approach and the use of assignments that encourage active student participation and collaboration, thus developing students' competency. Problem-solving methods, as proposed by Lesh and Zawojewski (2007), are effective in promoting student-centred learning and cultivating algebraic thinking skills. Radford (2014) and Boaler and Sengupta-Irving (2016) argued that specially designed classroom activities are necessary to support students' development in formal algebra and promote algebraic thinking. Additionally, Gurtner (1992), Godwin and Beswetherick (2003), supported by Hegedus and Kaput (2005), recommended structured tasks, the use of appropriate digital tools, and explicit interventions involving student interactions to cultivate students' algebraic thinking skills in the classroom.

Effects of Problem Solving and Technology on Student's Algebraic Thinking

There is little empirical data supporting the benefits of problem solving combined with technology in Malaysian classrooms, despite assertions regarding the beneficial effects of both on students' algebraic thinking abilities. Mustaffa et al. (2018) asserted in their study that the incorporation of algebraic reasoning into problem solving learning methodologies holds the potential to assist educators in enhancing the teaching and acquisition of algebra. By integrating algebraic reasoning into problem solving context, learners can develop a deeper understanding of algebra and its practical applications. The utilization of this framework is viable in virtual learning environments, allowing students to engage in algebraic reasoning activities with flexibility and adaptability. Research by Vagner Campeão and Carvalho (2021), discussed the development of Algebrizar, an applet designed to promote algebraic thinking in early elementary school. Algebrizar incorporates a playful approach to problem solving, treating it like a game with trails and scores to encourage students to think algebraically. This aligns the programme with the competencies and skills required by the official curriculum for this age group. According to research by Baysal and Sevinc (2021), using the bar model method in mathematics instruction can help students understand algebra better and solve problems more effectively, which in turn can help them develop their algebraic thinking abilities.

Bar model drawing is a useful tactic for improving elementary students' accuracy in arithmetic word problem solving and their capacity to apply cognitive strategies, according to Morin et al. (2017). The "model method" of teaching mathematics in Singaporean primary schools primarily uses bar diagrams to aid students in visualising the problem structures found in word problems. "AlgeBAR" is a software tool that was created to scaffold the learning of the algebraic process, specifically the formulation of equations, as described by Looi et al. (2007). This intervention pedagogy is technology-enabled, aiming to support students in transitioning from bar diagrams to algebraic problem-solving to develop algebraic thinking skills among students.

Infusion of Digital Bar Model into Polya's Problem Solving Model

Costa and Brandt (2001) contended that instructing students about the process of thinking, which emphasizes thinking as a subject matter, is insufficient in facilitating effective learning of thinking. They contend that using teaching strategies they refer to as "teaching for thinking," it is essential to create a classroom climate that encourages thinking. Thinking-Based Learning is a method that Swartz and his associates suggest (Swartz & Parks, 1994; Swartz et al., 2007). It involves teaching curriculum content and thinking skills at the same time in a lesson. Beyer (1997) posited that the enhancement of thinking-based learning can be achieved through the integration of teaching for thinking and teaching about thinking. The integration of these two approaches results in a more explicit, systematic, clear, and focused thinking-based learning process.

Accordingly, the current investigation implemented an infusion approach, wherein the process of solving algebraic problems, particularly utilizing Polya's problem-solving strategy alongside the digital bar model, is combined with teaching guidance on the development of cognitive and reasoning abilities. Through the utilization of digital bar models, which serve as pedagogical tools for fostering cognitive growth, students receive explicit instruction on enhancing their thinking skills within the framework of this pedagogical approach. Later, they are asked to use the digital bar model to solve algebraic problems using Polya (teaching for thinking). This study used a comprehensive infusion approach, wherein each algebraic problem was solved by concurrently completing the steps of the Polya and digital bar model. In order to better understand how seventh-grade students' algebraic thinking is affected when solving algebraic problems, this study utilized Polya's problem solving with the digital bar model teaching method.

The Framework for Algebraic Thinking Skills

Ralston's Algebraic Thinking Skills served as the foundation for the algebraic thinking framework used in this study. Three primary categories of algebraic thinking skills were identified by Kaput et al. (2008): generalized arithmetic, function, and modelling. More information about the connected aspects of these three constructs has been provided by Ralston (2013). Efficient calculation and generalisation are key components of the generalised arithmetic construct. Number pattern recognition is a component of functional thinking skills, whereas open problem solving, similarity detection, and variable computation are components of modelling.

Generalized Arithmetic

Generalised arithmetic, as described by Kaput et al. (2008), encompasses the study of algebraic systems and structures, incorporating relational and computational laws within mathematics. Fujii and Stephens (2001) suggested that teaching generalized arithmetic can advance students’ development in algebraic thinking, transitioning smoothly from basic arithmetic. Algebraic thinking is a thought process defined in the literature as the ability to discern and symbolize patterns in mathematical terms (Mason, 1989; Sfard & Linchevski, 1994). It heavily relies on one's skill to conceptualize and use generalizations and to employ suitable representational methods to convey these generalizations effectively. It is on the groundwork laid by basic arithmetic that these skills are built and further nurture the growth of algebraic thinking capabilities (Carpenter et al., 2005; Jacobs et al., 2007).

Function

According to Blanton and Kaput's (2005) research, lower secondary school students are capable of using a variety of representations when they are performing functional reasoning. This encompasses their capacity to simulate and resolve equations with indeterminate quantities employing symbolic language, as well as their adeptness in articulating covariations, recursive relations, and data matching both verbally and symbolically. The research carried out by Brizuela and Lara-Roth (2001), Carraher et al. (2007), Carraher and Schliemann (2007) and Moss London McNab (2011) corroborate the findings posited by Blanton and Kaput (2004). According to an analysis conducted by Blanton and Kaput (2004) with fifth-grade students, scaffolding can help students develop functional algebraic thinking skills. Students' cognitive processes can be shaped in a way that promotes a deeper comprehension of data and the capacity to interpret functional relationships more effectively by gradually introducing tables, graphs, pictures, words, and symbols.

Modelling

Ralston (2013) emphasized that modelling plays a pivotal role in fostering the development of algebraic thinking skills. This involves carrying out calculations involving variables, comprehending similarities, and solving open-number sentences. Students are indirectly introduced to variables and unknown values through assignments that call for filling in a blank with a value. This helps students understand how different arithmetic operations relate to one another. Additionally, a number of academics stress the significance of equality in helping students develop algebraic thinking abilities (Carpenter et al., 2005; Rittle-Johnson & Alibali, 1999). Riley-Johnson and Alibali (1999) elucidated that the symbol "equal to" encompasses three distinct connotations: the comparability of two magnitudes, a connection, and the existence of two components within an equation. Nonetheless, studies indicate that a lot of students struggle to comprehend variables, particularly when it comes to using them symbolically in algebra (Küchemann, 1978; Usiskin, 1988).

Purpose and Hypothesis

Previous research indicates that the utilization of problem solving in the learning process greatly enhances students' algebraic thinking. Moreover, various studies provide evidence that the integration of problem solving and thinking tools cultivates students' algebraic thinking skills. It has been demonstrated that problem solving promotes self-regulation and critical thinking, thereby facilitating the development of algebraic thinking skills. The utilization of the digital bar model in conjunction with Polya's problem-solving model has been shown to significantly gain proficiency in a wide range of algebraic thinking skills such as generalized arithmetic, functional analysis, and mathematical modelling. This integration enhances the ability to tackle algebraic problems effectively and fosters a deeper understanding of mathematical concepts within the context of problem-solving strategies. Although incorporating this method has shown promise for enhancing key elements of algebraic thinking, the extent of its positive impact on seventh-grade students remains unclear. Consequently, the main objective of this research is to determine the degree to which the integration of Polya's problem-solving with the digital bar model can foster seventh-grade students' algebraic thinking skills.

In order to determine the extent to which these interventions support students' algebraic thinking, this research used the Polya's problem-solving with digital bar model teaching method (PSDMB) and bar model teaching method (MB) to test the "Infusion Approach" hypothesis against the "non-infusion approach" hypothesis. Furthermore, the research assessed the degree to which the PSDMB and MB teaching methods have an effect on students' algebraic thinking skills, in comparison to the Conventional Problem Solving (CPS) method. Therefore, the PSDMB, MB, and CPS were the three teaching methods used in this study. Thus, the following alternative hypothesis was put forth:

> Students taught via the PSDMB teaching method would perform significantly higher than students taught via the MB teaching method, who in turn would perform significantly higher than students taught via the CPS teaching method in algebraic thinking skills.

Therefore, the purpose of this study was to determine how much the PSDMB teaching method could support the development of seventh graders' algebraic thinking abilities in the areas of i) Generalized Arithmetic; ii) Function; and iii) Modelling. In order to ascertain whether another Bar Model teaching method was just as successful in achieving the intended student outcomes, this study compared two distinct Polya with the Bar Model and Polya with non-Bar Model teaching methods. Thus, the purpose of this study was to find out if students who received intervention from three different teaching methods differed significantly in their ability to think algebraically.

Research Methodology

Design

To explore how three different teaching methods affect the teaching and learning of algebraic thinking among seventh graders, this study employed a quasi-experimental pre-test post-test control group design. The independent variables were the three teaching methods: PSDMB and MB (Experimental group) versus CPS (Control group). The dependent variables were the students' algebraic thinking abilities, specifically in Generalised Arithmetic, Function, and Modelling.

Sample

A total of 90 seventh graders from one rural fully government-funded secondary school in Tambunan, Sabah, Malaysia, participated as research sample. The school was selected based on the socio-demographic similarity, such that the students were similar in age and ethnicity. Students comprised of 48 (53.3%) females and 42 (46.7%) males aged 13 years old. The Kadazandusun is the largest ethnic group in the school, comprising both the Kadazan and Dusun tribes. Three classes were selected based on the comparable pre-test mean scores achieved by students in the Algebraic Thinking Test (ATT) and randomly assigned to one of the intervention groups as an intact group: the PSDMB, MB, or the CPS.

Research Ethics

The researcher obtained the cooperation and permission from the school to carry out the study. The researcher also obtained consent from the parents or guardians of the students involved. In addition, the researcher acquired the respondents' permission for their participation in the research. The permission was obtained through written documents. The researcher clarified the purpose of the research and explained that the data would be used as empirical data for the study. The information collected was only for research matters, and the participant's identity would not be exposed.

Instrument

Researchers developed an assessment tool known as the Algebraic Thinking Test (ATT) to evaluate the experimental treatments (Jahudin & Siew, 2023). Two identical and concurrent ATT were used as the pre-test and post-test. Nine open-ended, subjective questions made up each of the parallel ATT. The questions were created using the content of the Standard Document of Curriculum and Assessment of Seventh Grade Mathematics and the Curriculum Standard of Secondary School, with a particular emphasis on algebra and relations (Curriculum Development Division, 2017).

All items on the Algebraic Thinking Test (ATT) showed positive values, with PTMEA-CORR scores ranging from 0.46 to 0.92, indicating their alignment with the construct being measured. The ATT demonstrated strong reliability, with a Cronbach's alpha coefficient (KR-20) of 0.90. Additionally, the item separation index of 6.29 surpassed the threshold of 3.0, and the item reliability score of 0.98 fell within the excellent range (Sumintono & Widhiarso, 2015). These results suggest that the ATT has a favourable item distribution and is a valid and reliable tool for evaluating algebraic thinking among seventh graders.

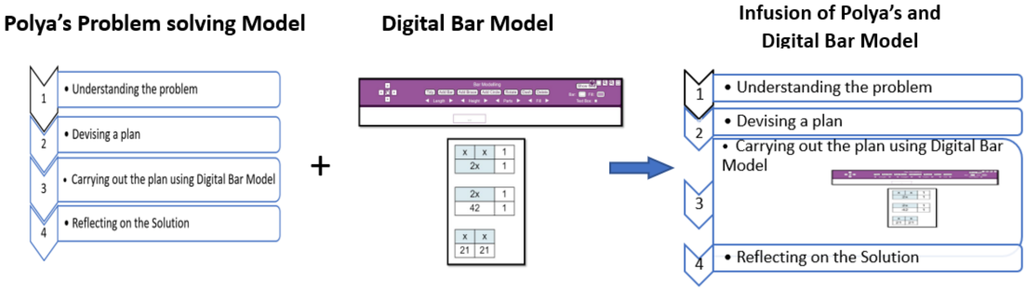
The Implementation of the Teaching Methods

PSDMB

High reliability and validity were found in the Polya and digital bar model learning module, known as the Algebraic Thinking Skills (ATS) module, which was created using Polya's (1945) and digital bar model (Jahudin & Siew, 2023). The main task in the ATS Module is the Polya's Problem-Solving Model (1945), which consists of four stages: (i) understanding the problem, (ii) devising a plan, (iii) carrying out the plan, and (iv) reflecting on the solution.

The infusion of Polya and the digital bar model learning module for the Seventh Graders included six learning activities on linear equations. In this study, the PSDMB method involved using the ATS module and the digital bar model method to help students solve algebraic problem-solving questions that require algebraic thinking skills. The implementation of strategies, the third step in Polya's problem-solving model, incorporated the digital bar model as an additional strategy (Figure 1). The PSDMB method was student-centred, with the teacher acting solely as a facilitator. Adapted from Ng and Lee (2009), this method also considered trial and error, reversal, elimination, and substitution methods in solving algebraic problems, particularly in Linear Equations, as outlined in the Curriculum Standard of Secondary School (CSSS) and the Standard Document of Curriculum and Assessment (SDCA) for Seventh Grade Mathematics.

Figure 1
Infusion of Digital Bar Model into the Polya's Problem-Solving Model


Polya's Problem solving Model
1 • Understanding the problem
2 • Devising a plan
3 • Carrying out the plan using Digital Bar Model
4 • Reflecting on the Solution
+
Digital Bar Model
x x 1
2x 1
2x 1
42 1
x x
21 21
Infusion of Polya's and Digital Bar Model
1 • Understanding the problem
2 • Devising a plan
3 • Carrying out the plan using Digital Bar Model
4 • Reflecting on the Solution

MB

The MB method is a teaching and learning approach that exposes students to algebraic problem-solving questions that require algebraic thinking skills, similar to those found in the ATS module. However, it transforms the digital bar model method into the regular bar model method by having students create their own bar drawings, which are used in Polya's Problem Solving Model at the implementation phase, which is the third step. Similar to PSDMB, this bar model method was also adapted from Ng and Lee (2009); like PSDMB, it is student-centred, with the teacher serving only as a facilitator. As specified in the Curriculum Standard of Secondary School (CSSS) and the Standard Document of Curriculum and Assessment (SDCA) of Seventh Grade Mathematics, the application of the bar model in this method also takes into account alternative approaches to solving algebraic problems, particularly in the topic of linear equations.

CPS

The conventional problem-solving method is a teaching and learning method where students are exposed to algebraic problem-solving questions that involve algebraic thinking skills as found in the ATS module. The conventional problem-solving method placed great emphasis on student-centred learning of algebra as stated in CSSS and the SDCA of Seventh grade Mathematics. Problem-solving methods such as trial and error, reversal, graph method, elimination, and substitution were applied in solving algebraic problems through the Polya Model, especially in the topic of Linear Equations without applying the digital bar model or regular bar model.

The Training of Teachers

The study involved a teacher who completed a two-week specialised training and coaching programme that concentrated on implementing PSDMB, MB, and CPS teaching methods. Before the study ever started, the teacher received a thorough ATS module that included details about Polya's approach to problem-solving, digital bar model, algebraic thinking skills and suggested results for every task. In addition, the teacher was trained in the PSDMB method of group activity facilitation. Through recurring in-person visits, the researchers closely observed the teacher to make sure that the implementation was dependable and consistent. The teacher was chosen on the basis of her readiness and willingness to take part in the study as well as her more than ten years of experience in teaching Mathematics. One teacher was assigned to teach the three classes using PSDMB, MB, and CPS, respectively, in order to eliminate any possibility of bias. The teacher conducted the intervention in three different classes over a 10-week period between October and November 2022, using different teaching and learning methods in each class.

Data Analysis

Preliminary Analysis

Preliminary analysis was undertaken to determine if the prerequisite assumptions for MANOVA and MANCOVA were satisfied. The analysis focused on the following assumptions for the statistical tests: (a) multivariate normal distribution; (b) equality of group population covariance matrices; (c) linear relationship between covariates and dependent variables; (d) absence of multicollinearity; and (e) homogeneity of variance in dependent variables.

Pre-Experimental Research

Pre-experimental research's main goal was to determine whether respondents in the three teaching groups had similar prior knowledge of pre-algebraic thinking (pre-AT), pre-generalized arithmetic (pre-GA), pre-function (pre-F), and pre-modelling (pre-M). A one-way multivariate analysis of variance (MANOVA) was performed to ascertain whether there were significant statistical differences in the mean scores on pre-AT, pre-GA, pre-F, and pre-M between the three groups. A univariate F-test (ANOVA) was performed to ascertain whether or not there were significant statistical differences between students in each of the three teaching groups on pre-AT, pre-GA, pre-F, and pre-M in situations where the overall multivariate test (MANOVA) did not produce significant results.

A multivariate analysis of covariance (MANCOVA) was carried out to look into the main effects of the three distinct teaching approaches on students' post-AT, post-GA, post-F, and post-M while controlling for the covariates (pre-AT, pre-GA, pre-F, and pre-M). Any unnecessary differences between the groups can be accounted for by removing the covariates' effects from the dependent variables using the MANCOVA (Hair et al., 1998). A univariate F-test (ANCOVA) was performed on the post-test mean scores using the pre-test mean scores as covariates if the overall multivariate test (MANCOVA) produced significant results. This was done in order to determine whether the teaching groups had a statistically significant main effect on the post-AT, post-GA, post-F, and post-M.

With SPSS for Windows (Version 22), the presumptions needed for the MANCOVA/MANOVA and inferential statistics analyses were examined. The Wilk's Lambda was utilised to evaluate the multivariate differences in this study, with a significance level of .05. This test is frequently used in multivariate analyses to look at differences between the means of identified subject groups on a variety of dependent variables (Everitt & Dunn, 1991). The eta square (η^2) was used to calculate the effect size index (f). Based on Cohen's approximate characterization (Cohen 1988, p. 284–288), $0.2 \leq f \leq 0.4$ is considered a small size effect, $0.4 < f \leq 0.7$, a medium size effect, and $0.7 < f \leq 1.0$, a large size effect.

Research Results

Preliminary Analysis

An initial examination showed that there was equal variance among the dependent variables, the data fit a multivariate normal distribution, a linear relationship was present between the covariates and the dependent variables, there was no issue with multicollinearity, and all the single and multiple variable preconditions for MANOVA/MANCOVA were met. However, the study found violations in the assumption of equal covariance matrices across groups in both the Pre ATT (Box's $M = 27.592$, $F(10, 16082.869) = 2.553$, $p < .01$) and Post ATT (Box's $M = 47.994$, $F(12, 36680.538) = 3.795$, $p < .01$) phases. According to Grice and Iwasaki (2007), Pillai's trace is a robust measure to counter the frequent breach of the equal group covariance assumption in MANOVA and MANCOVA. Hence, Pillai's trace was utilized as the multivariate criterion for determining the significance of the model in interpreting the outcomes of the analysis.

Descriptive Statistics

Table 1 provides an overview of the descriptive statistics for students' pre-and post-test scores in algebraic thinking skills, covering Generalized Arithmetic (GA), Function (F), and Modelling (M).

Table 1
Descriptive Statistics of the Dependent Variables

Dependent Variables	Intervention Group	*N*	Pre-Test		Post-Test	
			M	*SD*	*M*	*SD*
Algebraic Thinking (AT)	PSDMB	30	4.43	1.04	24.67	2.45
	MB	30	4.47	1.38	18.67	2.68
	CPS	30	5.93	2.48	13.00	2.98
	Total	90	4.94	1.48	18.78	5.49
Generalized Arithmetic (GA)	PSDMB	30	1.47	0.57	7.30	1.12
	MB	30	1.40	0.56	5.50	1.08
	CPS	30	1.70	0.59	3.83	0.87
	Total	90	1.52	0.58	5.58	1.72
Function (F)	PSDMB	30	1.27	0.45	9.33	1.40
	MB	30	1.30	0.53	6.50	1.20
	CPS	30	1.73	0.58	4.47	1.22
	Total	90	1.43	0.56	6.77	2.37
Modelling (M)	PSDMB	30	1.70	0.53	8.13	1.14
	MB	30	1.77	0.63	6.70	1.58
	CPS	30	2.57	0.73	4.60	1.73
	Total	90	2.01	0.74	6.48	2.08

The Pre-Experimental Research Results

MANOVA Analysis

There were no statistically significant differences between the three groups in Pre-AT, Pre-GA, Pre-F, and Pre-M, according to the results of the MANOVA and ANOVA (Table 2).

Table 2

Summary of Multivariate Analysis of Variance (MANOVA) Results and followed-up ANOVA Results on Pre-test mean Scores

MANOVA effect and dependent variables	Multivariate, *F*	Univariate, *F*
Group Effect	*df* = 8, 162 Pillai's Trace *F* = 12.462, *P* = .05	2, 58.815
Pre- AT		*F* = 2.625, *p* = .078
Pre- GA		*F* = 1.729, *p* = .184
Pre-F		*F* = 2.279, *p* = .108
Pre-M		*F* = 1.029, *p* = .362

The Experimental Research Results

The MANCOVA results showed that teaching methods had significant main effects on dependent variables [Pilai's Trace =.762, $F(8, 162) = 12.462$, $p < .05$]. Subsequent ANCOVA revealed that the teaching methods had significant main effects on AT [$F(2, 110.946) = 824.890$, $p <.05$], $\eta^2 =.721$], GA [$F(2, 82.916) = 86.142$, $p <.05$, $\eta^2 =.659$], F [$F(2, 93.429) = 149.846$, $p <.05$, $\eta^2 =.685$,], and M [$F(2, 29.714) = 69.414$, $p <.05$, $\eta^2 =.409$]. There was a strong correlation found between the teaching methods and the dependent variables, meaning that the teaching methods accounted for 72.1% of the variance in AT, 65.9% in GA, 68.5% in F, and 40.9% in M.

Subsequent analysis using the Post hoc pairwise test showed that seventh-grade students using the PSDMB method performed significantly better in AT, GA, F, and M than their peers in the MB group ($P_{AT} < .05$, $P_{GA} < .05$, $P_F < .05$, and $P_M < .05$, respectively). These students then significantly outperformed their peers in the CPS group ($P_{AT} < .05$, $P_{GA} < .05$, $P_F < .05$, and $P_M < .05$, respectively). As a result, the researchers failed to reject the alternative hypothesis postulated in the research.

Table 3 demonstrates a significant and very big effect size when comparing the PSDMB and CPS teaching methods in AT (4.27), GA (3.36), F (3.70), and M (2.41). In the meantime, the comparison between PSDMB and MB in AT (2.33), GA (1.64), F (2.18), and M (1.04) revealed a significant mix of big and fairly big effect sizes in the analysis. Comparing the MB and CPS in AT (2.03), GA (1.60), F (1.68), and M (1.27), on the other hand, revealed a significant and fairly big effect size.

Table 3
Summary of Post Hoc Pairwise Comparison

	Comparison Group	*MD*	*p*	Effect	Interpretation
Algebraic	PSDMB vs MB	5.996	< .05	2.33	Big
Thinking	PSDMB vs CPS	11.497	< .05	4.27	Big
(AT)	MB vs CPS	5.501	< .05	2.03	Big
Generalized	PSDMB vs MB	1.781	< .05	1.64	Big
Arithmetic	PSDMB vs CPS	3.433	< .05	3.36	Big
(GA)	MB vs CPS	1.652	< .05	1.60	Big
Function	PSDMB vs MB	2.820	< .05	2.18	Big
(F)	PSDMB vs CPS	4.683	< .05	3.70	Big
	MB vs CPS	1.863	< .05	1.68	Big
Modelling	PSDMB vs MB	1.430	< .05	1.04	Big
(M)	PSDMB vs CPS	3.381	< .05	2.41	Big
	MB vs CPS	1.951	< .05	1.27	Big

Discussion

In general, the findings of this study indicate that students who were taught using the PSDMB method achieved significantly higher level of performance compared to those taught using the MB method. Additionally, it was observed that students who were taught using the MB method achieved significantly higher level of performance compared to those taught using the CPS method in algebraic thinking skills, including Generalized Arithmetic, Function, and Modelling. When comparing the PSDMB and CPS methods and the PSDMB and MB methods, respectively, there is a significant effect size of more than one (1), indicating that the PSDMB method is the most successful teaching method for promoting algebraic thinking skills in seventh-grade students, including Generalised Arithmetic, Function and Modelling. With a comparatively large effect size, students who were taught using the MB method performed better overall than those who were taught using the CPS method.

The intervention using the ATS Module has effectively established a structured technology-aided learning environment for students to enhance their proficiency in algebraic thinking. This is consistent with the findings of a previous study conducted by Yerushalmy (2005) and Akcaoglu (2014), students who receive assistance with digital technology are capable of solving problems and illustrating functional connections between variables, thus indirectly bolstering their problem-solving skills. Denner et al. (2012) further supported that digital technologies contribute to the improvement of cognitive abilities and problem-solving aptitude. Additionally, Szabo et al. (2020) asserted that the integration of mathematical content into problem-solving endeavours can enhance 21st-century skills as well as algebraic thinking.

Moreover, exposure to the ATS Module also facilitates the development of students' algebraic thinking skills through engaging in complex problem-solving activities. By emphasizing reasoning over rote memorization, Polya's approach to problem-solving in algebra encourages critical thinking. The ATS Module also facilitates active digital learning, encouraging a constructivist approach that empowers students to generate new knowledge, tackle problems, and engage in critical thinking. The integration of the digital bar model into problem-solving processes enables students to comprehend and execute their problem-solving strategies. The heuristic method, particularly the implementation of the digital bar model aids students in comprehending abstract algebra through visual representation. The digital bar model employed as a visual tool in the PSDMB method enhances students' proficiency in solving algebraic problems and refining their algebraic thinking skills.

Despite the PSDMB method being superior to the MB method in terms of promoting algebraic thinking skills, the MB method still demonstrates a significant impact compared to the CPS method. The CPS method primarily focuses on one-directional learning approaches, which fail to provide students with well-structured cognitive activities, particularly those pertaining to algebraic thinking skills (Rahman et al., 2022; Ryandi et al., 2018). Conventional teaching methods, as highlighted by Beneke and Ostrisky (2008), prove inadequate in promoting active learning and fail to stimulate meaningful classroom discussions. Additionally, the reliance on teachers to regulate answers impedes students' ability to engage in fruitful discussions and develop their ideas. Consequently, the conventional teaching method obstructs the development of students' algebraic thinking skills.

Generalized Arithmetic

The PSDMB method utilizing Polya problem-solving models and digital bar models has effectively provided students with opportunities to enhance their algebraic thinking skills in arithmetic generalizations that involve the efficient manipulation of numbers and generalizations. The utilization of digital visualization, particularly through digital bar models, facilitates the creation of data images that aid in the communication of information. This process requires the conversion of data from one form to another. Consequently, data visualization assists students in developing a straightforward approach to perceiving data, allowing them to quickly identify and showcase uncommon patterns before they can cultivate their thinking abilities. Ziatdinov and Valles (2022) further emphasized the numerous advantages of digital applications, such as GeoGebra, in the fields of algebra, calculus, physics, and linear programming. These applications consistently contribute to the enhancement of students' performance, capabilities, and comprehension due to their inherent characteristics, which enable students to engage in visual learning, particularly for complex and concise topics.

The PSDMB method can expand generalization and formalization involving the articulation and representation of unifying ideas that make the mathematical relationship clearly visible with the presence of digital technology. Digital technology is thought to be extremely significant in the teaching and learning of algebra (Bokhove & Drijvers, 2012; Kieran, 2007), and it has an overall positive impact on mathematical achievement (Li & Ma, 2010; Slavin & Lake, 2008). Furthermore, the results of a study by Kieran (2007) showed that early algebra learning is significantly impacted by technology use. Students' participation in technology-based learning is also boosted by this exposure to the digital world (McCrindle & Fell, 2019). In order to stimulate students' interest and speed up learning, educators have begun integrating technology into the curriculum and the teaching and learning process.

Although the findings demonstrate the proficiency of students in the PSDMB method in mastering the construct of algebraic thinking skills in arithmetic generalization, the results also indicate that the proficiency of arithmetic generalization among MB students is superior to that of the CPS method. This study is supported by the findings of Wong et al. (2020) study, which indicate that the bar model can enhance students' ability to construct mathematical models based on their understanding of arithmetic concepts compared to conventional methods of problem solving. This is because the use of the bar model assists students in solving high-level mathematical problems. The Bar model serves as a tool for students to reinforce understanding and identify relationships between operations and appropriate solutions in order to find reasonable answers. This is further supported by the study of Baoler (2016), which indicates that students are able to interpret problems by drawing rectangular bars to symbolize problem situations with their correct and accurate solutions compared to conventional problem-solving methods.

Function

The students' capacity to represent connections between distinct quantities using symbols, variables, and equations in the PSDMB and MB learning methods was also observed in their mean scores gained in this study. The findings revealed that the Function construct in the PSDMB method resulted in a significantly higher mean score compared to the MB method. This difference can be attributed to the well-planned instruction and utilization of the digital bar model as a supplementary tool in solving algebraic problems in the PSDMB method. According to Cuban (2001), visual aids, particularly those related to the sense of vision, contribute significantly to students' comprehension, accounting for up to 83% of the impact. The integration of bar model applications in the form of digital technology in PSDMB methods enhances students' problem-solving abilities. These findings align with the studies conducted by Shabiralyani et al. (2015) and Asad et al. (2016), which indicate that the use of visual materials such as pictures, animations, videos, and films stimulates thinking, initiates discussion and ultimately improves the quality of learning.

It is found that the achievement of students using the PSDMB method surpasses that of the MB method in the construct of Function. Moreno and Fuentes (2021) supported that teaching and learning in mathematical activities designed within a technological environment stimulate and maintain positive conditions in the classroom, enhance the process of experimentation, visualization, reasoning, and direct communication through student-centred learning. The ATS Module-based learning not only incorporates technology but also emphasizes student-centred instruction, providing a new dimension for students to nurture their creativity while engaging in the formulation of relationships among variables, patterns, and similarities through brainstorming activities. The way students generalize and establish relationships influences their justification of solutions (Ellis, 2007). Implicitly, as students generalize, establish relationships, and provide justification, their communication and creativity are also enhanced, contributing to the cultivation of their algebraic thinking skills in Function.

The results of the study revealed a significant difference in the mean scores between the MB method and the CPS method. These findings indicate that the MB method excels in facilitating relationships and providing justifications, thereby enhancing communication and creativity in the resolution of algebraic problems. A study conducted by Khairiree (2019) also found that lower secondary school students are capable of representing associations and relationships using the bar model. This implies that the utilization of bar models in discussing associations, relationships, and patterns has a notable impact on students' ability to solve algebraic problems.

The results of this study are further corroborated by the research conducted by Hofer (2015), which demonstrates that children have the capacity to comprehend mathematical concepts and appreciate the significance of relationships through tangible experiences utilizing the Bar Model. As such, this method serves to bridge the divide between the concrete and the abstract. Wong et al. (2020) contended that the bar model provides a more efficient and widely accepted approach to the instruction of mathematics. In instances where conventional teaching methods prove ineffective, it becomes imperative to periodically introduce innovative interventions. The systematic process of implementing the bar model strategy can assist in addressing learning disabilities that impede students' proficiency of functional thinking skills, in contrast to the CPS method. This discrepancy emerges due to the fact that the CPS method employs a teaching approach that places emphasis on the Polya problem-solving throughout the teaching and learning process yet lacks opportunities for students to engage in critical thinking in the absence of aids such as bar models.

Modelling

The final construct in stimulating algebra thinking skills is a skill in modelling thinking, where students should demonstrate their ability to use variables, especially in problem-solving, and understand the concept of equality and the meaning of the "equal to" symbol. In the development of modelling, students who follow PSDMB interventions have progressed through a phase of comprehending problems based on visual bar models (Kriegler, 2008), reasoning algebraically through the context of generalizations and relationships that are formed and represented in various forms such as symbols and diagrams (Blanton et al., 2017), and structuring complex data systematically through heuristic methods (Marshall et al., 2006). Diagrams based on heuristic concepts also elucidate the quantity within the context of the narrative and the relationship that exists between them, aiding in the comprehension of abstract concepts and consequently facilitating the problem-solving process (Bishop, 1989). The PSDMB teaching and learning method encourages students to approach algebraic questions in a more systematic manner, guiding them step by step towards finding solutions and promoting a more open exploration throughout the process of understanding problems, formulating solution strategies, implementing those strategies, and revising selected solutions, with the availability of digital bar model.

While the MB method showed a lower level of performance in the construct of modelling compared to the PSDMB method, the achievement of the post-test mean scores of the MB method showed a significant improvement and a large effect size compared to the CPS method. This is consistent with the findings of the Pratiwi et al. (2020) study, which demonstrated that the achievement of algebraic thinking skills in students who learn to use diagrams and bar modelling is superior to that of students who learn using conventional approaches. This is because the application of tables and diagrams involves a process of translating abstract concepts and utilizing symbols to represent concrete objects, thereby enhancing students' understanding. Consequently, the use of algebraic problem-solving approaches to improve algebraic thinking skills with the assistance of bar model methods is highly recommended in the teaching and learning of algebra. This is because the MB method conveys the structure and relationships within the problem in a meaningful manner (Winn, 1987) while enhancing students' understanding of algebra due to the inclusion of three different modes of representation in the bar drawing, namely text-shaped solution questions, diagrams representing relationships, and symbols and equations (Ng & Lee, 2009).

The difference in mean scores between the MB and CPS methods was also interpreted by Buzan (2002) that the deliberate utilization of visual aids in learning would stimulate the simultaneous utilization of the left brain and right brain, thereby facilitating the development of thinking in the student's cognitive abilities and enabling effective teaching of thinking. This study's findings are also supported by Chan and Foong (2013), who explained that teaching aids like the bar model shift the focus from the final answer to the work process and the relationship between known and unknown quantities. This approach enhances students' abilities and thinking through the systematic compilation of ideas, thus facilitating abstraction in algebraic learning.

Additionally, the CPS teaching and learning method, which had the lowest post-mean scores in modelling compared to the PSDMB and MB methods and decreased by the end of the study, was due to the lack of prioritisation in teaching thinking. Changwong et al. (2018) pointed out that the absence of a clear emphasis on teaching thinking approaches hinders students' proficiency and deters them from fully applying contexts for problem-solving to develop their algebraic thinking skills (Booker & Bond, 2009; Kaput, 2008; Kaput et al., 2008; Lins et al., 2001; Schliemann et al., 2003). Toma and Greca (2018) and Afsari et al. (2021) stressed that conventional teaching and learning methods without any teaching aids fail to create an active and interactive discussion environment, which hinders students' ability to engage in idea exchange and solution formation. Furthermore, Khalaf and Zin (2018) stressed that students place a great deal of trust in their teachers, believing that they will have a significant influence on the learning environment in the classroom. The intended learning objectives are difficult to attain because of the students' passive behaviour and lack of proactive engagement.

Conclusions

The current study addresses the existing gap in the literature by utilizing the Polya's problem solving with digital bar model teaching method (PSDMB) through the use of a self-developed Algebraic Thinking Skill module (ATS). The purpose of this module is to enhance the algebraic thinking abilities of seventh-grade students on the topic of linear equations. The findings of the study indicate that students who were taught using the PSDMB method demonstrated a higher level of algebraic thinking skills compared to those taught using the MB and CPS methods. These results suggest that explicit teaching on thinking skills has a greater impact on students. However, it is important to note that creating a learning environment that promotes algebraic thinking solely through the use of problem-solving techniques and bar models is not sufficient. The inclusion of a digital module that explicitly teaches about thinking is necessary in order to effectively cultivate algebraic thinking and solve algebraic problems. This research highlights the importance of incorporating the teaching of algebraic thinking skills through the infusion of Polya's problem-solving techniques and digital bar model into secondary school mathematics lessons. By doing so, students' algebraic thinking abilities can be enhanced in the aspects of Generalized Arithmetic, Function, and Modelling.

This study offers strong evidence that, in order to promote algebraic thinking in students, primary and secondary school math teachers should include problem-solving strategies and thinking skills instruction (particularly, the use of digital bar models) in their algebra curricula. Additionally, this study encourages more research into the possible benefits of utilising various teaching strategies and thinking aids to encourage seventh-grade students to think algebraically about specific subjects. It is pertinent to recognise the limitations of the PSDMB infusion method, even though the study's findings indicate that it greatly improves seventh-grade students' algebraic thinking. With 30 students per teaching method, the study's sample size was quite small and might not be entirely representative of all secondary school students. Furthermore, following lessons learned in 10 weeks, the research's quantitative data were gathered and examined. Future studies can use a mixed methods approach, with more learning activities, a longer study period, and a larger sample size in order to fully assess the impact of using digital bar models in solving algebraic problems. Additionally, comparing rural and urban schools would shed light on how students' algebraic thinking is impacted by their surroundings in algebra classes.

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Declaration of Interest

The authors declare no competing interest.

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LEVELS OF FACTORS INFLUENCING THE 21ST-CENTURY MATHEMATICS TEACHING CHALLENGES FOR SECONDARY STUDENTS IN THE SECONDARY EDUCATIONAL SERVICE AREA OFFICE OF LOPBURI: A STRUCTURAL EQUATION MODELING APPROACH

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Abstract

Student's attitude towards 21st-century mathematics teaching is affected by factors such as content knowledge, knowledge of teaching and learning activities, attitude towards mathematics and technology knowledge. The aim of this study was to construct structural equation models for investigating 21st-century mathematics teaching and learning among secondary mathematics students in the Secondary Educational Service Area Office Lopburi (SEAOL). Quantitative research used the 21st-century TPACK framework. The research sample consisted of 400 SEAOL students from the 1/2022 semester using multi-stage sampling. A questionnaire was used to assess 21st-century secondary school mathematics teaching and learning with a 0.934 confidence of. The data was analyzed using the appropriate software and revealed key components and their relationships. The results show that teaching and learning, fundamental technology capability, content knowledge, specialized technology use, and mathematical content implementation all affected mathematics teaching in the 21st-century for SEAOL students. Influence was .89, .70, .63, .25, and .21. School technology support has a .59 effect on students' basic technological skills. Technology's role in learning influenced students' technology use by .21. This research shows how each aspect affects 21st-century mathematics education at the SEAOL, and math overload had the least effect. Teachers and stakeholders should investigate and innovate to improve the use of specialized technology in teaching to help students acquire higher-level mathematical content and apply it in their daily lives.

Keywords: *mathematics secondary students, mathematics teaching, structural equation model, Thailand*

Introduction

This synthesis encompasses findings from six research studies conducted by Chariyamakarn and Sukpan (2018); Hanhaw (2018); Saethow (2019); Sirithon et al (2020); Sripongpird (2018) and Soythong (2019) on the factors influencing the teaching and learning of mathematics in contemporary times. The collective results highlight that content knowledge, knowledge of teaching and learning activities, attitude towards mathematics, and technology

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knowledge are the primary factors impacting mathematics instruction. Furthermore, to align with the principles of 21st-century teaching and learning, it is essential to adapt the teaching methods from passive learning to a more interactive process. This involves engaging students in reading, listening to lectures, and actively utilizing content from books and textbooks. Traditionally, teachers would provide comprehensive explanations while students took notes, with knowledge assessed through exams. This approach is commonly known as a teacher-centered method. However, in the 21st-century, there has been a shift in the learning process, transforming the role of teachers from lecturers to facilitators who design activities to stimulate student learning (pedagogy). The emphasis is now on empowering students to explore and construct knowledge independently. Teachers play a supportive role by providing guidance and suggesting various tools, particularly through the integration of technology. This approach requires teachers to be adept at designing learning activities that integrate technology, known as TPACK, to facilitate efficient and extensive access to knowledge. Moreover, collaborative learning with classmates, where knowledge is exchanged, is emphasized as an active learning process, placing students at the center of their learning experience. According to the Office of the Basic Education Commission (OBEC) (2017), this student-centered approach promotes active learning and encourages students to take an active role in acquiring knowledge.

Furthermore, the researcher conducted a study analyzing the factors influencing mathematics teaching and learning in the 21st-century among students under the Secondary Education Area Office Lopburi (SEAOL). Factor analysis was employed to examine these factors. The research findings revealed seven key factors impacting the teaching and learning of mathematics in this context: They are as follows: (1) Supporting the use of technology from schools; (2) Demand for technology in teaching and learning; (3) Basic technology proficiency; (4) Specialized technology proficiency; (5) Content knowledge; (6) Excessive mathematics content for implementation; and (7) Teaching and learning approaches. These findings were identified by Tiengyoo (2023), as presented in Appendix 1.

In this research, our focus was to delve deeper into the examination of the seven factors that impact the teaching and learning of mathematics in the 21st-century among school students under the SEAOL. The aim is to determine the extent of influence each factor holds in the present context. To achieve this structural equation models that elucidate the factors influencing mathematics teaching and learning, the Analysis of Moment Structure (AMOS) software package was utilized for confirmatory component analysis and to ensure model consistency.

Research Problem

Despite existing research and interest in the factors influencing mathematics teaching and learning among students in the 21st-century, which has provided insights into the factors affecting mathematics teaching and learning among these students, the research has not adequately demonstrated the varying degrees of importance of these factors on teaching and learning. Additionally, the characteristics of students in each region exhibit differing influences from these factors. Therefore, the goal was to investigate the impact levels of these factors on mathematics teaching in the 21st century for students in SEAOL.

Research Focus

(1) Factors that impact mathematics teaching and learning in the 21st-century encompass various variables expected to influence the effectiveness of instructional practices. These factors include: 1) Awareness about the use of technology: This refers to the understanding and perception of the necessity and benefits of integrating technology into mathematics teaching; 2) Technology knowledge: This entails the proficiency in utilizing different technologies

for teaching mathematics, such as word processors, electronic spreadsheets, presentations, geodynamics, programming languages, internet access, data storage, and modern technology implementation; 3) Content knowledge: This refers to the comprehension and mastery of mathematical content necessary for effective teaching, including the ability to explain concepts and understand the origins of mathematical content; 4) Teaching and learning activities: This encompasses the instructional styles and methods employed by teachers in mathematics teaching and learning. These dimensions have been explored in previous studies conducted by Koehler et al. (2013), Saethow (2019), Sirithorn et al. (2020), and Sripongpird (2018). To measure these factors, the researcher developed a questionnaire specifically designed to assess the impact of these variables on mathematics teaching and learning in the 21st-century.

(2) The factors that influence students' teaching and learning of mathematics in the 21st-century are observational variables, which include: 1) Supporting the use of technology from schools (Access_FAC1); 2) Requiring technology for teaching (Access_FAC2); 3) Relating to basic technology proficiency (TK_FAC1); 4) Associated with specialized technology proficiency (TK_FAC2); 5) Relating to content knowledge (CK_FAC1); 6) Pertaining to the mathematical content deemed more essential for implementation (CK_FAC2); and 7) Influencing teaching and learning (IA_FAC1). These factors have been identified through an analysis of the variables impacting students' teaching and learning of mathematics in the 21st-century, as conducted by Tiengyoo (2023).

(3) Secondary Education Service Area Office Lopburi (SEAOL) is an educational institution in Thailand responsible for overseeing secondary education in the Lopburi province.

(4) The term 'school' under the SEAOL refers to educational institutions within the office's jurisdiction. These schools are typically medium-sized or larger, with a total student population of 500 or more (SEAOL, 2022).

(5) In the context of the SEAOL, a 'student' refers to an individual enrolled in a medium-sized or larger school under its jurisdiction. These schools are classified as medium schools or higher in terms of their size, and students are aged between 13 and 18.

Research Aim and Research Questions

The general objective of the study is to revalidate the instruments in the SEAOL context and to propose a structural model that will portray the influences of teaching and learning, fundamental technology capability, content knowledge, specialized technology use and mathematical content implementation all affected mathematics teaching in the 21st-century for SEAOL students. School technology support has an effect on student's basic technological skills. Technology's role in learning influences students' technology use.

Research Methodology

Background

This research adopts a quantitative approach and employs literature reviews and relevant theoretical frameworks to make the findings more comprehensive. Descriptive statistical analysis and Factor Analysis (Tiengyoo, 2023) are used, along with SEM. The results are discussed, summarized, and supplemented, with recommendations for additional research. The AMOS software program was used to analyze SEM.

Sample

The population for this research consisted of 17,916 secondary school students from 13 schools affiliated with the SEAOL (2022), which are classified as medium-sized or larger schools. The sample size used in the study comprised 400 secondary school students selected from seven schools affiliated with the SEAOL, specifically from the first semester of the academic year 2022. The sample was obtained using multistage sampling. The sample size was determined using the Yamane formula (Yamane, 1970) with a sampling error of 0.5. For statistical analysis using *SEM*, the research followed the recommendation of Kline (2010) to have a sample size of at least 200 in the study. This is in line with Hair et al. (2010), who suggested that a minimum sample size of 300 is suitable for *SEM* analysis when the number of latent variables is less than or equal to seven. Therefore, the sample size chosen for this research was considered appropriate.

Instrument and Procedures

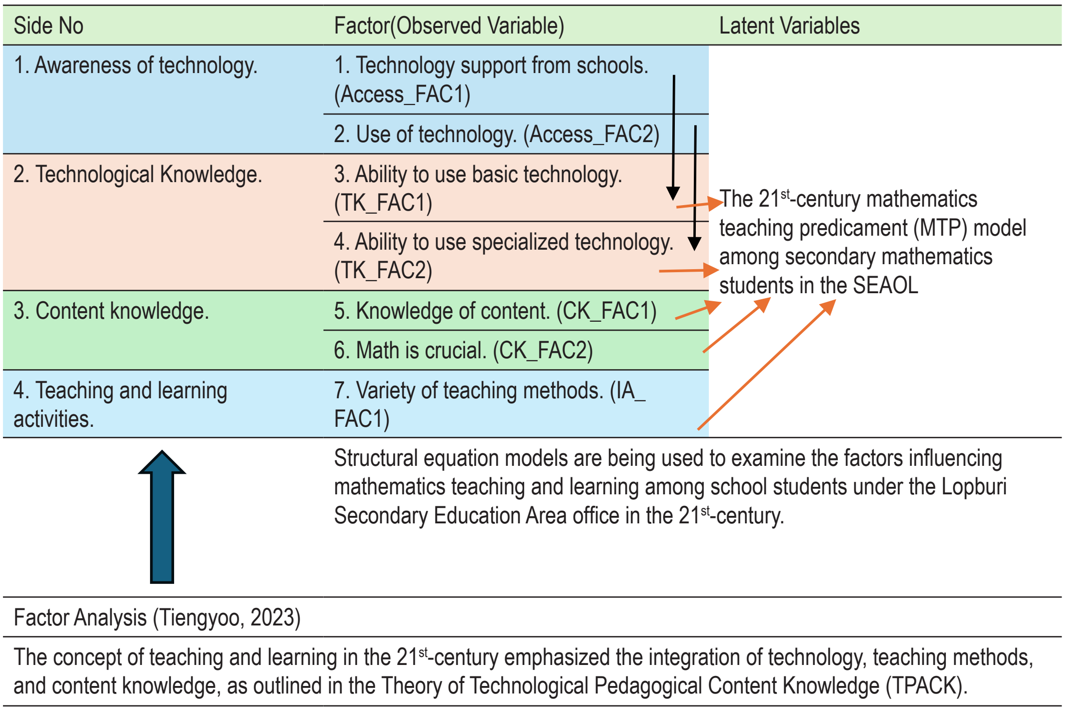
In this research, questionnaires were used to assess the factors influencing the teaching and learning of mathematics in the 21st century among secondary school students. The questionnaire comprised 37 items, which were measured using a 5-point rating scale. The overall reliability of the questionnaire was assessed using Cronbach's alpha coefficient, yielding a confidence value of .934 (Tiengyoo, 2023).

Data Analysis

The statistical tests employed to assess the fundamental assumptions for *SEM* analysis included examining Skewness, Kurtosis, and Multicollinearity. These tests involved assessing measures such as Tolerance and Variance Inflation Factor (*VIF*) statistics. The research employed statistical techniques such as confirmatory factor analysis and structural equation modeling. The assessment of model fit was based on various model fit index values, as recommended by Hair et al. (2010) a p-value of 0.05, $CMIN/DF \leq 2.00$, $GFI \geq 0.90$, $TLI \geq 0.90$, $CFI \geq 0.90$, $NFI \geq 0.90$ and $RMSEA \leq 0.08$. Additionally, construct reliability (*PC*) and average variance extracted (*PV*) were considered, with *PC* values higher than 0.60 and *PV* values higher than 0.50 considered acceptable and having a loading score value greater than 0.3, following the guidelines proposed by Kaiwan (2013). To collect the necessary information, we obtained permission from the seven schools included in the sample to administer the questionnaires. The questionnaires were distributed online via Google Forms from May 30 to June 30, 2022. We ensured the accuracy, completeness, and validity of the collected data through data validation procedures. The data was then coded and processed using appropriate computer programs.

Research Conceptual Framework

Figure 1
Research Concept



Side No	Factor(Observed Variable)	Latent Variables
1. Awareness of technology.	1. Technology support from schools. (Access_FAC1)	The 21st-century mathematics teaching predicament (MTP) model among secondary mathematics students in the SEAOL
	2. Use of technology. (Access_FAC2)	
2. Technological Knowledge.	3. Ability to use basic technology. (TK_FAC1)	
	4. Ability to use specialized technology. (TK_FAC2)	
3. Content knowledge.	5. Knowledge of content. (CK_FAC1)	
	6. Math is crucial. (CK_FAC2)	
4. Teaching and learning activities.	7. Variety of teaching methods. (IA_FAC1)	

Structural equation models are being used to examine the factors influencing mathematics teaching and learning among school students under the Lopburi Secondary Education Area office in the 21st-century.

Factor Analysis (Tiengyoo, 2023)

The concept of teaching and learning in the 21st-century emphasized the integration of technology, teaching methods, and content knowledge, as outlined in the Theory of Technological Pedagogical Content Knowledge (TPACK).

Research Results

The distribution analysis of the data revealed that the Skewness values ranged from -0.869 to -0.146, while the Kurtosis values ranged from -0.410 to 1.819. These values indicate that the variables exhibit Skewness within the acceptable range of -3 to 3 and Kurtosis within the range of -10 to 10. Therefore, the variables demonstrated a normal distribution, as illustrated in Table 1.

Table 1
Presents the Values of Skewness, Dominance, Tolerance, and VIF for the Observed Variables

Observational variables	Skewness	Kurtosis	Tolerance	*VIF*
Access_FAC1	-0.622	-0.027	0.531	1.882
Access_FAC2	-0.869	1.819	0.718	1.394
TK_FAC1	-0.659	0.394	0.454	2.201
TK_FAC2	-0.157	-0.410	0.702	1.425
CK_FAC1	-0.146	0.440	0.553	1.808
CK_FAC2	-0.204	0.190	0.872	1.147
IA_FAC1	-0.369	-0.202	0.430	2.324

The tolerance values range from 0.430 to 0.872, while the *VIF* values range from 1.147 to 2.324. The tolerance values are all above the minimum threshold of 0.1, and the *VIF* values are all below the maximum threshold of 10. These findings indicate that there is a low level of correlation among the observed variables. Therefore, it can be concluded that the observed variables are independent of each other, and there is no issue of excessive correlation (multicollinearity) among the variables and (3) The *SEM* analyzing the factors influencing the teaching and learning of mathematics in the 21st-century among secondary school students under the SEAOL were analyzed for their affirmative composition. The analysis considered standard element weight values and observed variables from the conformity analysis of the *SEM*. The results of the analysis indicate that the *p*-value index of χ^2, *CMIN/DF*, *GFI*, *TLI*, *CFI*, *NFI*, and *RMSEA* all meet the criteria. Therefore, it can be concluded that the *SEM* of factors influencing the teaching and learning of mathematics in the 21st-century among secondary school students under the SEAOL is in accordance with the empirical data. These results are summarized in Table 2.

Table 2
Statistics for Model Conformity Check

Index	Acceptable value of consistency (criteria)	Statistics obtained
χ^2	$p > .05$	0.283
CMIN/DF	≤ 2.00	1.238
GFI	≥ 0.90	0.995
TLI	≥ 0.90	0.994
CFI	≥ 0.90	0.998
NFI	≥ 0.90	0.991
RMSEA	≤ 0.08	0.024

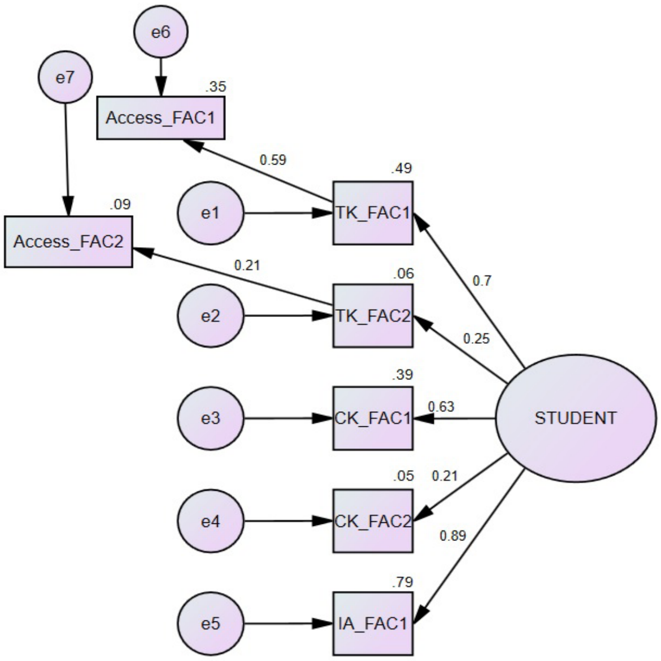
Table 3
Standard Element Weight Values of Observational Variables in SEM for Factors Influencing Mathematics Teaching in the 21st-century of Secondary School Students under the SEAOL

Organization/Variable	Standardized factor loading	*SE*	R^2	*PC*	*PV*
Students				0.80	0.500785
TK_FAC1	0.70	0.812	0.49		
TK_FAC2	0.25	0.388	0.06		
CK_FAC1	0.63	0.797	0.39		
CK_FAC2	0.21	***	0.05		
IA_FAC1	0.89	1.092	0.79		
TK_FAC1					
Access_FAC1	0.59	0.040	0.35		
TK_FAC2					
Access_FAC2	0.21	0.046	0.09		

Note: *** Mandatory parameters (Constrain)

From the analysis presented in Table 3, the results indicate affirmative elements of the model. The *PV* was calculated to be 0.500785. Moreover, considering the precision statistics of the *PC* being greater than 0.60, it demonstrates that the teacher variable accurately captures 80% of the factors influencing mathematics teaching in the 21st-century among secondary school students. Additionally, the *PV* being greater than 0.05 signifies that the teacher variable accounts for 50% of the description of the factors influencing mathematics teaching among secondary school students. Factors supporting the use of technology from schools had a minimal influence 0.05 on students' ability to use basic technology. On the other hand, the demand for technology for learning showed a stronger influence 0.21 on students' ability to use specific technologies.

Figure 2
SEM of Factors Influencing Mathematics Teaching in the 21st-century



Chi-square = 7.429, df = 6, p = .283, Chi-square/df = 1.238, GFI = .995
TLI = .994i, CFI = .998, NFI = .991, RMSEA = .024

Figure 1 illustrates the influential elements on the teaching and learning of mathematics in the 21st-century among secondary school students under the SEAOL. These elements include the ability to use technology from schools, content knowledge, the ability to use specialized technology, and mathematics content beyond what is necessary for implementation. Their respective levels of influence, in descending order, are .89, .70, .63, .25, and .21. School technology support has a .59 effect on students’ basic technological skills. Technology's role in learning influenced students' technology use by .21.

Discussion

The research results indicate that, currently, the factors of teaching and learning exert the greatest influence on the teaching and learning of mathematics in the 21st-century among secondary school students under the SEAOL. This can be attributed to the Ministry of Education's policy aimed at enhancing the quality of teaching management. The policy emphasizes reducing the duration of academic or theoretical classes while maintaining essential curriculum content that students should grasp according to established standards. It also grants teachers the flexibility to adapt teaching methods and organize learning activities, allowing students to engage in more practical and meaningful learning experiences. Under the initiative of the "reduced study time, moderate class, more knowledge" project, which aligns with the teaching and learning reform in the Thai era 4.0, the emphasis is placed on fostering meaningful learning for students. The focus is to create a relaxed and stress-free classroom environment where students have ample time for age-appropriate activities and explore their potential. Memorization of texts is no longer the sole focus; instead, teachers assume a reduced role in delivering direct messages to students. Their primary responsibility lies in organizing learning processes and activities that stimulate students' enthusiasm for learning and promote a diverse range of learning activities. Teachers are encouraged to adopt an active teaching approach, wherein they become facilitators of learning rather than mere information providers. This approach, known as active learning, involves organizing teaching activities based on established standards and indicators across all subject areas. Active learning methods are employed not only within the classroom but also in student development activities and other learning enhancement initiatives (Churches, 2016; Kharbach, 2015; March, 2012; & OBEC, 2019). Furthermore, Mazen (2021) has posited an alternative methodology for pedagogy and acquisition of knowledge that aligns with the OBEC Ministry of Education's principles, namely, the implementation of a constructivist approach to teaching and learning. The paramount objective is to direct the attention of pupils towards the acquisition and investigation of knowledge through the utilization of technology as the primary instrument for pedagogy and scholarship. The objective is to cultivate an ambience conducive to learning and foster a sense of curiosity that will enable students to independently generate novel insights. According to Gilakjani et al (2013) perspective, the limited involvement of teachers as mere mentors may pose certain obstacles for students in their pursuit of learning and executing tasks. Moreover, it affords learners the chance to engage in deeper contemplation or action at the crux of the topic, free from the encumbrances of computations or any extraneous elements that do not contribute to the learning process.

The second most significant factor influencing the teaching and learning of mathematics in the 21st-century among school students under the SEAOL is the integration of information technology in education and the effects of the COVID-19 situation on the educational landscape (Cristóbal et al, 2020). To effectively incorporate technology into teaching and learning and enhance teachers' abilities, three approaches are recommended. Firstly, policy guidelines should promote comprehensive and ongoing training programs that equip teachers with the necessary skills to effectively utilize technology as a medium of instruction. Secondly, educational institutions should encourage teachers to embrace information technology in their daily lives and integrate it into their teaching practices. Finally, this can be achieved by providing support and professional development opportunities for teachers in different subject areas and age groups who may require additional technology skills. By leveraging technology across various platforms, teachers can create learning environments that connect students to the outside world, fostering curiosity and enabling them to explore new and engaging content beyond the scope of traditional lessons. This approach emphasizes the importance of using technology as a tool to stimulate students' curiosity and prepare them for acquiring essential skills in today's era (Promsatien & Nettananomsak, 2021). The aforementioned statement aligns with the research conducted by Martinez (2022) and Paul and Tendeukai (2015), which suggested that incorporating diverse technological tools in the process of teaching and learning can expedite students' comprehension and improve their overall learning efficacy. Moreover, it facilitates the development of self-assurance among students and promotes an enjoyable learning experience. The utilization of technology in tandem with mathematical concepts must be achieved before progress can be made.

The COVID-19 pandemic has presented an opportunity for innovative approaches in teaching and learning. As people were confined to their homes, remote learning became a prevalent method. As the situation improved, a blended learning model emerged, combining in-person and remote classes. It was observed that blended learning was the most suitable approach during the pandemic (Schvenger, 2018). Teachers had to adapt their teaching methods and processes accordingly. They transitioned from traditional classroom settings to a blended approach, requiring them to design and experiment with new teaching strategies. This shift had implications for various aspects, including classroom arrangement, teaching materials, instructional sessions, and assessments. It highlighted the need for improvements in learning assessment protocols and criteria (Promsatien & Nettananomsak, 2021).

Content literacy factors play a significant role in the teaching and learning of mathematics in the 21st-century among secondary school students under the SEAOL. A strong foundation in mathematics content is crucial for successful learning outcomes in this era. Mathematics fosters creativity, logical thinking, systematic problem-solving abilities, and the capacity to analyze and determine solutions accurately. Moreover, mathematics serves as a vital tool for studying science, technology, and other disciplines, contributing to the development of skilled human resources and economic growth on an international scale. Consequently, continuous development of mathematics education is essential to remain current and aligned with economic conditions. With rapid advancements in science and technology in the era of globalization, achieving success in mathematics learning poses a significant challenge. Students need to be prepared to acquire knowledge, pursue career paths, or pursue higher education upon graduation. Therefore, educational institutions should tailor learning experiences to match the potential of individual learners. Mathematics is divided into three strands: number and algebra, measurement and geometry, and statistics and probability. These strands cover various topics such as the real number system, algebraic expressions, geometric figures, statistical analysis, and probability calculations. Additionally, mathematical skills and processes are essential for effectively applying knowledge in daily life. These skills encompass problem-solving abilities, communication through mathematical language and symbols, the utilization of mathematical knowledge as a learning tool, reasoning and critical thinking, and the cultivation of creativity to expand existing ideas and generate new knowledge (Institute for the Promotion of Teaching Science and Technology, 2019; OBEC, 2017).

Conclusions and Implications

Teaching and learning, fundamental technology capability, content knowledge, specialized technology use, and mathematical content implementation all affected mathematics teaching in the 21st-century for SEAOL students. Influence was .89, .70, .63, .25, and .21. School technology support has a .59 effect on students' basic technological skills. Technology's role in learning influenced students' technology use by .21. The factors of the ability to use specialized technology and mathematical content go beyond what is merely required for implementation. These factors, at the fourth and fifth levels of influence, significantly impact the teaching and learning of mathematics in the 21st-century among secondary school students under the SEAOL. This suggests that teachers' utilization of specialized technology to support teaching and learning is currently at a relatively lower level. However, it is crucial for teachers to incorporate specialized technology as it can enhance students' understanding of advanced mathematical concepts and their practical application in real-life situations.

Recommendations

Recommendations for Utilization of Research Results

The findings of this research indicate the varying levels of influence of factors affecting the teaching and learning of mathematics in the 21st-century among school students under the SEAOL. Among these factors, the excessive mathematics content necessary for application has the least impact. It is recommended that teachers and relevant individuals engage in research and innovation to effectively integrate specialized technologies into teaching and learning practices. By doing so, students can better comprehend complex mathematical concepts and apply them in real-life situations. The introduction of technology as a valuable tool in teaching and learning should be facilitated through teachers who play a crucial role in guiding students' educational journey.

Suggestions on Conducting the Next Research

(1) For future research, it is recommended to collect data from larger populations, including regional and national samples. By comparing the differences in the influence of each factor on the teaching and learning of mathematics in the 21st-century across different regions, it will be possible to develop mathematics teachers in various areas of Thailand based on the specific strengths and weaknesses identified within each region.

(2) Another avenue for investigation would involve studying the relationship between each factor influencing mathematics teaching and learning in the 21st-century through the analysis of Structural Equation Models (*SEMs*) within different regions of Thailand.

(3) Additionally, exploring the readiness of mathematics teachers in educational institutions regarding the integration of technology, teaching methods, and content knowledge can be achieved through the analysis of *SEM*.

(4) Teachers and relevant stakeholders should conduct research and innovation in the utilization of specific technologies to enhance teaching and learning. For example, exploring the use of graphing calculators in mathematics instruction can be a valuable area of focus.

(5) Furthermore, it is suggested that teachers and related individuals conduct research on active learning approaches within different mathematics subject areas, considering grade levels. This could involve exploring Activity-Based Learning, Project-Based Learning, Experiential Learning, Problem-Based Learning, and other similar methodologies. The organization of these learning activities should revolve around a central concept: empowering learners to play an active role in their own education. When designing learning experiences, careful consideration should be given to the learner's characteristics, setting clear instructional goals, employing appropriate teaching methods and learning activities, and implementing effective assessment strategies.

Declaration of Interest

The authors declare no competing interest.

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Appendix 1

Factors Affecting Current Mathematics Teaching and Learning in SEAOL of Students

Effective mathematics education required	Variable, (Load score)	Factor
Awareness of technology (AC)	AC_215: Does your school or organization have a printer? (.695)	1. Technology support from schools. (Access_FAC1)
	AC_212: Does your school or organization support cloud storage, such as Google Drive or Microsoft OneDrive? , (.694)	
	AC_217: Does your school or organization prioritize programming in a particular language, such as Python, C, C++, or Java? , (.680)	
	AC_211: Does your school or organization have enough computers for use? , (.640)	
	AC_213: Does your school or organization support teaching software, such as Microsoft Office or Zoom Meeting? , (.625)	
	AC_214: Does your school have projectors? , (.624)	
	AC_216: Does your school or organization have high-speed internet access or Wi-Fi? , (.615)	
	AC_2111: Do you want to use technology in teaching because it helps create learning innovation and improves teaching and learning? , (.858)	2. Use of technology. (Access_FAC2)
	AC_2110: Do you want to use technology for teaching because it makes it easier for students to research and find information? , (.836)	
	AC_219: Do you want to use technology for teaching because it serves as an intermediary for communication both inside and outside the school or organization? , (.817)	
	AC_218: Do you want to use technology to teach because it helps students understand the lesson more concretely? , (.755)	
	AC_2112: Can knowledge of technology contribute to the efficiency of teaching and learning? , (.738)	
Technological Knowledge (TK)	TK_226: Can you communicate via the internet using tools like email, Line, or Messenger? , (.773)	3. Ability to use basic technology. (TK_FAC1)
	TK_221: Can you use a word processor such as Microsoft Word or Google Docs? , (.744)	
	TK_223: Can you use a presentation program such as PowerPoint or Google Slides? , (.693)	
	TK_2210: Do you believe that technological knowledge affects the teaching and learning of mathematics today? , (.689)	
	TK_228: Do you keep up with modern technology and constantly study its use? , (.644)	
	TK_227: You have the option to store a wide range of data, including flashcards, CDs, DVDs, Google Drive, or Dropbox., (.635)	
	TK_225: Can you program in a specific language, such as C, C++, Python, or Java?, (.823)	4. Ability to use specialized technology. (TK_FAC2)
	TK_224: Can you use dynamic geometry software such as GSP or GeoGebra? , (.809)	
	TK_229: Can you use specialized software as a medium for teaching mathematics, such as Scratch? , (.628)	
	TK_222: Can you use an electronic spreadsheet such as Microsoft Excel or Google Sheets? , (.605)	

Effective mathematics education required	Variable, (Load score)	Factor
Content knowledge (CK)	CK_233: Can you apply your knowledge correctly? , (.838)	5. Knowledge of content. (CK_FAC1)
	CK_232: Can you explain the origin of the teachings? , (.835)	
	CK_231: Can you identify or explain the meaning of the subject matter being taught? , (.786)	
	CK_236: What do you think is the current content of mathematics instruction? Does it respond to learners' needs? , (.722)	
	CK_234: Are you always seeking more knowledge from up-to-date sources? , (.692)	
	CK_237: Do you believe that having complex math problems will affect the effectiveness of teaching and learning mathematics? , (.460)	
	CK_235: What do you think is the content of mathematics in secondary school that is currently being taught? Is there more than necessary for the future use of learners? , (.939)	6. Math is crucial. (CK_FAC2)
Teaching and learning activities (IA)	IA_246: Is technology important for stimulating and creating ideas to help learners better understand the subject matter of mathematics? , (.815)	7. Variety of teaching methods. (IA_FAC1)
	IA_247: Do you consider the selection of teaching techniques or methods suitable for presenting mathematics subject matter to make it easier for learners to grasp the concept of a lesson? , (.806)	
	IA_245: Do you believe that learners will feel more interested in the lesson when combining teaching styles with the use of technology? , (.802)	
	IA_248: Can using technology to create teaching materials that are appropriate to the context of mathematics content help learners build their own knowledge of those contents? , (.802)	
	IA_243: Are you satisfied when organizing teaching and learning activities that emphasize the exchange of knowledge between learners and learners or learners and teachers? , (.753)	
	IA_244: Are you satisfied when organizing teaching and learning activities where learners can create their own predictive messages? , (.710)	
	IA_242: Are you satisfied when organizing teaching and learning activities that focus on students practicing on their own?, (.613)	
	IA_241: Do you enjoy the narrative teaching method? , (.329)	

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- results of research;
- discussion;
- conclusions and/or implications;
- acknowledgements (if any);
- references (in APA style, 7th Ed);
- appendix (if any).

P.S. The structure can be different if the paper is only theoretical qualitative research.

The length of the manuscript

The manuscript should be not shorter than 6 pages (including references, tables and figures). Manuscripts should be typed on A4, in Times New Roman 12-point font size, single-spaced, 2.5 cm with all the margins, word-document (Word 6.0 or later) format.

Acronyms

Acronyms should be defined the first time they appear.

Tables and figures

Tables and figures should be valuable, relevant, and visually attractive. Tables (made in Word or another software) and figures must be referred to in the text and numbered in the order of their appearance. Each table and figure should have a complete, descriptive title; and each table column an appropriate heading. The texts in tables and figures should be 11-point (in some cases 10) and their width should be 12 cm at maximum. The figures should be in format .jpg (unless done in Word or Excel); resolution 1200 dpi. Figures, tables (black and white colour, without ground-colour) and captions should be inserted within the manuscript at their appropriate locations. All the graphics (figures) must be editable. The font size should be Times New Roman for all figures and tables. Figures should be carefully explained in the text and cited in numerical order.
It is the author's responsibility to obtain permission to reproduce illustrations, tables, etc. from other publications.

Discussion

Focus the discussion to the two important questions: What is already known about your topic? What your research adds? It is recommended that the aim and major findings of the research should be reminded. And then the similarities and differences of the findings with previous research studies should be exemplified in detail.

Conclusions

This part is not a summary. Bring out the significance of your research. Show how you've brought closure to the research problem, and point out remaining gaps in knowledge by suggesting issues for further research. The main research outcome should be clearly seen.

References

The title „References" must be used. APA style for writing references in the text and in the reference list must be used. References in the text should be presented in parentheses (Knox, 1988; Martin, 1995). If necessary, the page can be indicated: (Martin, 1995, p. 48). The list of references should be presented after the text.
The author should make sure that there is a strict one-to-one correspondence between the names and years in the text and those on the list. All the references should be listed in alphabeti¬cal order by author's name.
For the sake of accuracy, references should always be as updated as possible, also in the interest of the readers and researchers on the topic the paper is dealing with.

Notes

Note 1: Manuscripts in which references are not in the APAstyle will be returned without review.

Note 2: References to online sources should include the type of medium (such as "serial online" or "monograph online"), the date of that specific reference (if applicable), the uniform resource locator (URL), and the date that the source was accessed. A source accessed online should al-ways be referenced accordingly, even if it is also published in printed form.

Note 3: All papers must meet the criteria of originality and scientific quality. Obviously, they must also comply with style and format requirements. The paper will not be subject to further review, if the manuscript is NOT WITHIN THE SCOPE and/or there is POOR USAGE OF LANGUAGE (all manuscripts must be written in clear and grammatical English).

Note 4: Submitted papers will be assessed based on their novelty, technical quality, potential impact, and clarity of writing.

Note 5: All papers are checked by CrossCheck system.

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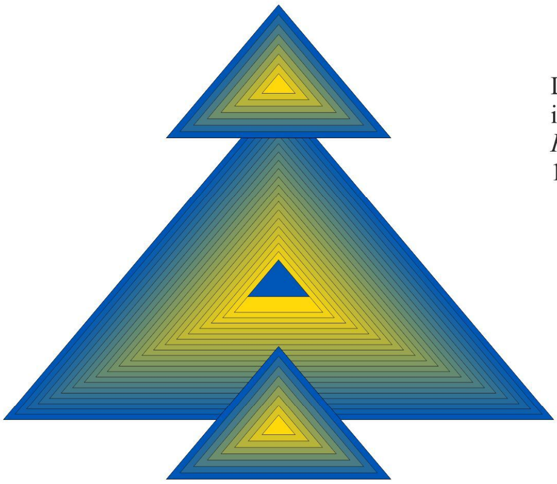
...'There is no doubt that education creates a man. On the other hand, man is an extremely complex structure. We usually arrive at two opposite but complementary conclusions. On the one hand, all the people we meet, and as far as we can guess, are generally in some way similar to each other. On the other hand, each person is somehow unique, different from others. Commonality and particularity/uniqueness are the two main cognitive categories of any phenomenon. It is understood that man, as a subject of activity, is “an open” system: his existence and development depend on relations with the world around him, in which he lives and works. So, firstly, man, like any living being, is part of the natural world and is rightly considered a biological organism. Secondly, any human being is a member of one or another society, with which he is connected by ties and relations, defined as a social individual. In addition, a person is, in one way or another, related to the socio-historical, cultural, and moral experience of mankind. How to adopt this experience? How to absorb?'...



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